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TECHNOLOGY UTILIZATION BIBLIOGRAPHY

Technology Utilization Division

Bibliography on WELDING METHODS

WITH INDEXES

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA SP-5024

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WITH INDEXES

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C.

February, 1966

NOTE

FOREWORD

The Administrator of the National Aeronautics and Space Administration has established a technology utilization program for "the rapid dissemination of information. . . .on technological developments. . . .which appear to be useful for general industrial application." From a variety of sources, including NASA Research Centers and NASA contractors, space-related technology is collected and screened; and that which has potential industrial use is made generally available. Information from the nation's space program is thus made available to American industry, including the latest developments in materials, management systems, processes, products, techniques and analytical and design procedures.

This publication is a part of a series of bibliographic publications intended to serve both scientific and technical personnel and the libraries and librarians who support them.

THE DIRECTOR, *Technology Utilization Division*
National Aeronautics and Space Administration

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INTRODUCTION

This bibliography is designed to assess and identify the current literature on the applications and uses of various welding methods.

The purpose of this series of publications is to provide industry with summarizing information on innovations contained in NASA and other space technology literature.

The bibliographies are intended to indicate the wealth of new information and new technology available from the collections of the National Aeronautics and Space Administration. It is the purpose of the Technology Utilization Bibliographies to select and list available information of special interest to the industrial user.

The format for this series has therefore been designed to permit a variety of forms of utilization. The bound volume provides for circulation among personnel who would be most likely to benefit from the material. At the same time, it serves as a permanent record for library filing and reference.

AVAILABILITY OF DOCUMENTS

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> Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151
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A-accession numbers, e.g., A63-12345, identify published journal articles and books which have been announced in *International Aerospace Abstracts (IAA)*, a journal published by the American Institute of Aeronautics and Astronautics. Articles are available for examination in those libraries that maintain sets of scientific and technical journals, and, in some instances, reprints may be obtained from the journal offices. Inquiries concerning books should be addressed to the publisher.

Abbreviations that frequently appear in the citations describing the references are listed below:

Abbreviation	Full Meaning
CFSTI	Clearinghouse for Federal Scientific and Technical Information
OTS	Office of Technical Services
ph	Photostat. Full size copies of the document are available in photostatic form
mi	Microfiche. Copies of the document are available in microfilm form
MF	Microfiche. See mi
HC	Hardcopy. See ph

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TPA ENTRIES

N62-13546 Missile and Space Systems Div., Douglas Aircraft Co., Inc., Santa Monica, Calif.
MOTOR CASE FABRICATION FROM WIDE CLOSE-TOLERANCE STEEL SHEETS. [Covering period Dec. 1961-Apr. 1962.]
Bernard B. Moss. May 1962. 34 p.
(Contract AF 33(600)-39653)
(ASD-TR-62-7-787)

Six missile motor cases of the second stage Nike-Zeus configuration were manufactured by roll-and-weld fabrication methods. In these cases the processing technique of resistance seam welding heat treated components was employed All six satisfactorily met the proof test at a theoretical hoop stress of 237,000 psi. (Author Abstract)

N62-13632 Battelle Memorial Inst., Columbus, Ohio.
CAUSES OF MICROFLAWS IN HIGH-STRENGTH WELD METALS, THEIR EFFECTS, AND METHODS OF ELIMINATING THEM. Final Report.
M. D. Randall, R. E. Monroe, and P. J. Rieppel. July 31, 1961. 68 p. 13 refs.
(Contract DA-33-019-ORD-3402)
(WAL TF 542.4/1)

Welds are deposited in air-melted and vacuum-melted 300M steel by the inert-gas-shielded, tungsten-arc, and electron-beam welding processes. Tension, bend, and impact tests were made of these weldments and base plates. Extensive metallographic examination and supplementary studies were made It was determined that (1) microdefects can cause low-load failure, (2) these defects occur at temperatures near the alloy solidus temperature and are chemistry controlled, (3) microsegregation of sulfur, phosphorus, and silicon occurs in these welds, (4) silicon lowers elevated-temperature ductility and promotes hot cracking, and (5) grain-boundary liquation of heat-affected zones occurs. (Author Abstract)

N62-14288 Aeroprojects, Inc., West Chester, Pa.
ULTRASONIC WELDING OF REFRACTORY METALS. Progress Report No. 8, for the Period 1 Apr. through 31 May 1962.
Harold L. McKaig, Jr. July 19, 1962. 3 p. 2 refs.
(Contract NOw 61-0410-c)

The objective was to develop a nondestructive weld inspection method since crack formation occurs when joining refractory metals by both conventional and ultrasonic methods. A surface-wave inspection method, based on Lamb wave propagation, appears promising for detecting cracks and for evaluating the size of the bonded area. For crack inspection, a single pulse-echo (transmitter-receiver) transducer would be used. In the absence of internal discontinuities, the normal interface and back reflection of the acoustic energy, is shown by two pips on the oscilloscope screen. A crack would be indicated by an additional pip, which would fall between the other two. With sufficient resolution, both the size and location of the crack can be estimated. For bond quality evaluation, two transducers would be used. The pip size associated with the receiving transducer would be standardized under controlled conditions for a good bond area. In the case of a bond area smaller than the one used for standardization, less energy would be transmitted, and consequently, the received pip would be reduced in size. Further development work and evaluation will be required to substantiate the validity and practicality of these inspection techniques. (P.F.E.)

N62-14939 DuPont de Nemours (E. I.) and Co. Savannah River Lab., Aiken, S.C.
A POWER SUPPLY FOR AN ELECTRON BEAM WELDER.
Harold S. Sanders. June 1962. 12 p. 1 ref.
(Contract AT(07-2)-1)
(DP-731) OTS: $0.50.

A high voltage supply for an electron beam welder was constructed from a surplus Oak Ridge Alpha I calutron power supply. An electron gun with horizontal and vertical position adjustment was constructed and installed in a rebuilt dry box. (Author Abstract)

N62-15279 Battelle Memorial Inst., Columbus, Ohio.
INVESTIGATION TO DETERMINE CAUSES OF FISSURING IN STAINLESS STEEL AND NICKEL-BASE-ALLOY WELD METALS. [Final] Technical Documentary Report [7 Nov. 1960 to 31 Dec 1961].
J. N. Cordea, R. M. Dvans, and D. C. Martin. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, June 1962. 58 p. 5 refs.
(Contract AF 33(616)-7702)
(ASD-TDR-62-317)

This report summarizes the first year's work in a long-term research program being conducted to investigate causes of fissuring in Type 310 stainless steel and Inconel alloy weld metals. Characteristics of fissures in welds in hot-tension specimens were studied and materials examined were: (1) Inconel and Type 310 stainless steel welds made from commercial electrodes, (2) hot-tension specimens made from commercially available Inconel and Type 310 stainless steel materials, (3) hot-tension specimens made from alloys prepared with electrolytic grades of iron, chromium, and nickel. All fissures were intergranular or interdendritic. In hot-tension specimens, they were usually oriented perpendicular to the tensile axis. The onset of fissuring corresponded to a drop in hot ductility and hot strength at high temperatures. Commercial alloys having high impurity concentrations always had lower hot-tensile properties than high-purity vacuum-melted alloys. When controlled amounts of carbon, silicon, and sulfur were added to vacuum-melted heats of Type 310 stainless steel, their

hot-tensile properties approached those of the commercial alloys. The occurrence of intergranular fissuring was attributed to increased amounts of grain-boundary segregation in the specimens. Electron-probe analyses and metallographic examinations of the grain boundaries verified this effect. Test results showed that large amounts of grain-boundary segregation occurred when (1) the original impurity concentration in the alloy was high, and (2) large grains were formed in the microstructures at the high temperatures.
(Author Abstract)

N62-15384 Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn.
HIGH-VOLTAGE ELECTRON BEAM WELDING OF AEROSPACE COMPONENTS.
Harry A. Hokanson. N.Y., Soc. of Automotive Engineers, [1962] 5 p. Presented at the SAE National Aeronautic Meeting, N.Y., Apr. 3-6, 1962.
(SAE Paper 514B)
High-voltage electron beam welding is discussed for a variety of aerospace applications. These include repair welding, welding of miniature electronic components, and welding of structural hardware. The specific procedure for each application is presented. Particular emphasis is placed on the contribution of the characteristics of the process (low energy input, high-purity welding environment, and precise controllability) to the success of each application.
(Author Abstract)

N62-15390 Alloyd Electronics Corp., Cambridge, Mass.
ELECTRON BEAM WELDING TECHNIQUES AS APPLIED TO AEROSPACE STRUCTURES.
Robert Bakish. N.Y., Soc. of Automotive Engineers, [1962]. 11 p. 17 refs. Presented at the SAE National Aeronautic Meeting, N.Y., Apr. 3-6, 1962.
(SAE Paper 514A)
This paper discusses electron beams and their generation, sources for electron beam information and manufacturers of electron beam welding machines, tooling for electron beam welding, accomplishments with electron beams in joining aerospace materials, and the future of electron beams in welding technology. (Author Abstract)

N62-16273 Aeroprojects, Inc., West Chester, Pa.
DEVELOPMENT OF ULTRASONIC WELDING EQUIPMENT FOR REFRACTORY METALS. Interim Technical Progress Report, Feb. through Aug. 1962.
Nicholas Maropis. Wright-Patterson AFB, Ohio, Manufacturing Technology Lab., May 1962. 37 p. 28 refs.
(Contract AF 33(600)-43026)
(ASD-TR-7-888 (III))
The requirements established during Phase I for a heavy-duty ultrasonic welding system are being analyzed, and associated development problems are being resolved. High-power ceramic transducer assemblies, powerforce programing elements, and switching devices for a motor-alternator power source are being assembled and experimentally evaluated. Current information on refractory metal developments affecting the ultrasonic weldability of such material, as well as data on candidate welding tip materials, is being accumulated and studied. (Author Abstract)

N62-17264 Armour Research Foundation, Chicago, Ill.
INVESTIGATION OF HEAT TREATMENT AND WELDING CHARACTERISTICS OF B-120 VCA TITANIUM ALLOY SHEET, PART II (Final Report)
John F. Rudy Aug. 30, 1962 62 p 8 refs
(Contract NOw 60-0351-c)
(ARF-2211-5)
Studies on heat treatment and welding technique were continued in an effort to improve the tensile properties of B-120 VCA in the aged condition. Special welding techniques were not effective in enhancing the aged weld metal tensile properties. Cold rolling after welding provided improved tensile properties in the as-rolled and the rolled and aged conditions, depending on the desired strength. Aging treatment at 800° F provided improved properties, either as the complete isothermal age or as the first stage in a duplex (800° to 1000° F) age. Useful weld metal tensile properties were obtained over a wide strength range, but the weld metal properties are still considerably deficient to those of the base metal. The physical metallurgy of the aging and duplex aging reactions was substantiated indirectly by electron microscopy and elastic modulus measurements. Aging is apparently due to precipitation of ω and α phases, and ω disappears in the early stages of post-age annealing (1000 F. Author

N62-17661 Stanford Research Inst. Poulter Labs., Menlo Park, Calif.
EXPLOSIVE WELDING
Donald E. Davenport Detroit, Am. Soc. of Tool and Mfg. Engr., 1962 17 p 4 refs For Presentation at the Creative Mfg. Seminars, 1961-1962
(ASTME Paper SP62-77) Available from Am. Soc. of Tool and Mfg Engr., 10700 Puritan Ave., Detroit 38, Mich.
The general principles of explosive welding are presented based on work with the Al-Al weld. Shear tests and peel tests of the welds indicate that they can be stronger than the parent metal. Photomicrographs of a wide variety of other metals which have been explosively welded include copper, steel, titanium, niobium, molybdenum, and tantalum. Examination of several of the copper welds indicates evidence of diffusion at the interface. Author

1963
STAR ENTRIES

N63-10102 Defense Metals Information Center, Battelle Memorial Inst., Columbus, Ohio
ELECTRON-BEAM WELDING OF TUNGSTEN
R. E. Monroe and R. M. Evans May 21, 1962 19 p 3 refs
(Contract AF 33(616)-7747)
(DMIC-MEMO-152)
Reported progress on the electron-beam welding of commercially pure tungsten indicates that sound crack-free welds can be made if the weld is not restrained during welding. Although the data are not all consistent, welds which are smooth and have minimum fusion and heat-affected zone width should be the strongest and most ductile. Tensile strengths are equivalent to the base metal near the recrystallization temperature but are appreciably lower at room temperature. The ductile-to-brittle transition temperatures for electron-beam-welded tungsten are above that of the base metal. The impact resistance of electron-beam-welded tungsten is very low. Electron-beam welding of tungsten parts should be thoroughly evaluated on production prototypes before specifying its use. B.J.C.

N63-10704 Thompson Ramo Wooldridge, Inc., Inglewood, Calif.
INVESTIGATION OF WELDING OF COMMERCIAL COLUMBIUM ALLOYS Final Report [16 Jan. 1961-15 Jan. 1962]
J. M. Gerken and J. M. Faulkner Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, May 1962 148 p 20 refs
(Contract AF 33(616)-7796)
(ASD-TDR-62-292)
An investigation was made of the welding characteristics of three commercial columbium base alloys, FS82, D31, and F48. Tungsten inert gas, electron beam, spot, and flash butt welding methods were

included in this investigation. The effect of the welding variables' travel speed, shielding gas composition and purity, filler metal additions, preheat and post heat were studied. Thermal cycles were measured in the fusion zone and heat-affected zone of TIG welds to help explain mechanical properties and microstructure on the basis of physical metallurgy of each alloy. The effect of welding on all alloys was to increase the ductile to brittle transition temperature. The electron beam welding process consistently produced more ductile welds than the TIG process. Author

N63-10774 European Atomic Energy Community, Brussels (Belgium)

ELECTRON BEAM WELDING OF SINTERED ALUMINIUM

M. Meulemans, D. Tytgat, J. Van Audenhove (CEN), J. Briola, and P. Jehenson (Euratom) Centre d'Étude de l'Energie Nucléaire, Mol (Belgium), Oct. 1962 22 p 20 refs

(Contracts Euratom 001-60-4 ORG-B and 022-61-7 ORG-B)

(EUR-39.e) Available from Belgian American Bank and Trust Co., N.Y., account No. 121.86: 30 Belg. Fr.

The high gas content of normal SAP (sintered aluminum products) caused two phenomena which limited the possibilities of welding by electron beam bombardment: (a) ionization and (b) metallic projections. Resulting porosity in the welded zone has been observed. High temperature testing under pressure has been used to verify the quality of the welds. Use of external pressure on the tube during welding leads to high-quality closures equal to or superior to other types of welds because of the very high, localized heating. Electron beam welding can be systematically used as a quality test for gas content in the material. Author

N63-12583 Defense Metals Information Center, Battelle Memorial Inst., Columbus, Ohio

JOINING OF NICKEL-BASE ALLOYS

R. M. Evans Dec. 20, 1962 77 p 60 refs

(Contract AF 33(616)-7747)

(DMIC-181)

The key to the success of many devices that are to be used in corrosive or high-temperature environments is often an ability to properly weld the nickel-base alloys. Alloys such as Monel, Inconel, etc., that do not depend upon relatively complex metallurgical reactions to obtain their desirable properties are not difficult to weld if proper procedures are used. Alloys which are relatively new (René 41, Hastelloy R-235, Inconel X, etc.) and do depend on complex metallurgical reactions to develop their useful properties present many joining problems. This report covers in a general way the criteria for the successful fabrication of several alloys which fall in each category. Fusion welding, resistance welding, and brazing are covered. The welding of dissimilar nickel-base-alloy combinations and repair welding are also discussed. Author

N63-15402 Naval Air Material Center Aeronautical Materials Lab., Philadelphia, Pa

INVESTIGATION OF SPOT WELDING CHARACTERISTICS OF TITANIUM ALLOYS

Edward F Deesing Nov 28, 1961 24 p

(NAMC-AML-1319)

The fatigue strength of multiple spot-welded joints in 060-in thick sheet material of the titanium alloys 4A1-3Mo-IV, 16V-2 5A1, and 6A1-4V were determined The fatigue strength of the three alloys was found to be 8 to 10% of the static strength of the spot-welded joint The alpha-beta alloy 4A1-3Mo-1V had the highest fatigue strength, the 16V-2 5A1, all beta alloy, the lowest Data are also presented on the elevated-temperature strength of spot welds and the effect of exposure to elevated temperature on room-temperature strength of spot welds in the 4A1-3Mo-1V alloy A uniform decrease in shear strength was noted with increase in temperature At an exposure temperature of 600° F, the 4A1-3Mo-1V alloy retained its strength up to 250-hrs exposure time A uniform decrease in shear strength occurred after exposure at 900° F for 100 hrs but an anomalous increase in strength occurred after exposure of 1000 hrs Author

N63-15862 National Aeronautics and Space Administration Marshall Space Flight Center Huntsville Ala

APPLICATIONS NOTES: SELECTED WELDING TECHNIQUES

Washington NASA Apr 1963 31 p

(NASA SP-501) GPO $0 30

Tools and techniques developed by the George C Marshall Space Flight Center for the welding of aluminum plates and sheets are described A seam tracker device and proximity control unit proved effective in welding heavy-gage aluminum Two segmented backup bars provide most of the back bar functions A special vacuum type backup bar facilitates repairs in normally inaccessible locations Tape retains and shapes the molten underbead without weld contamination and proves useful for backup tasks Handy fitup tools for fusion welding hold workpieces in near perfect alinement Alinement of large-diameter cylinders is maintained by direct current straight-polarity TIG tack welding Guide tips are developed for feeding fiber wire when welding with inert gas processes Improved method of electric-arc spot welding utilizes the sigma technique N E A

N63-16204 Battelle Memorial Inst Columbus Ohio

DEVELOPMENT OF PROCEDURES FOR WELDING 2-INCH-THICK TITANIUM-ALLOY PLATE Final Report

W J Lewis G E Faulkner and D C Martin July 31 1962 42 p 5 refs

(Contract NOw-60-0390-c)

Procedures were developed for welding 2 inch thick titanium alloy plate, i e A-70, Ti-5Al-2 5Sn Ti-6Al-4V and Ti-3V-11Cr 3Al alloys Results show that heavy titanium-alloy plates can be satisfactorily welded provided that they are adequately protected from weld contamination and that the compositions of the filler wire and base plate are properly controlled A controlled atmosphere welding chamber was used to provide protection for the welds However, similar results can be expected in open air welding operations if adequate shielding methods are developed for protecting welds from contamination N E A

N63-16322 Hamilton Standard Div. United Aircraft Corp. Windsor Locks, Conn

ELECTRON BEAM WELDING OF AEROSPACE MATERIALS [Final Report]

William I Kern and Lawrence E Lubin Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Feb 1963 191 p 6 refs

(Contract AF 33(657)-7763)

(ASD-TDR-63-132)

High-voltage electron-beam welding techniques capable of producing butt welds of optimum strength and ductility were developed for B120VCA titanium D6AC steel molybdenum-0 5% titanium to tungsten, and beryllium Welds were produced in material thicknesses of 0 125 inch for the B120VCA titanium 0 290 inch and 0 090 inch for the D6AC steel, 0 100 inch and 0 050 inch, and 0 005 inch for the molybdenum-0 5% titanium welded to tungsten, and 0 040 inch for the beryllium The effects of thermal treatments (aging and heat treating) were investigated in the B120VCA and D6AC by welding and testing a variety of weld-thermal treatment combinations Results of the metallographic and mechanical property investigations of the electron beam welds were compared with base-metal properties and with published data for other joining techniques Author

N63-20426 Battelle Memorial Inst., Columbus, Ohio Defense Metals Information Center

WELDABILITY STUDIES OF THREE COMMERCIAL COLUMBIUM BASE ALLOYS

P A Kammer and R E Monroe June 17 1963 22 p
(Contract AF 33(616)-7747)
(DMIC Memo 169)

A group of columbium-base alloys is being considered for addition to the Department of Defense Refractory Metals Sheet Rolling Program Good weldability is one of the requirements for inclusion of alloys in this program Two alloys currently under consideration are B 66 produced by Westinghouse Electric Corporation, and FS 85, produced by Fansteel Metallurgical Corporation A third alloy, C-129, produced by Wah Chang and submitted by Boeing Airplane Company was also included in this evaluation Samples of these three alloys were obtained for a brief weldability evaluation at Battelle to determine whether the alloys met the target properties established by the Materials Advisory Board, Refractory Metals Sheet Rolling Panel-Alloy Requirements and Selection Group Room-temperature bend ductility target properties for fabricable columbium base alloys are 1T for base metal bends and 2T for welds bent with the weld transverse to the bend axis Bend tests made on base-metal samples showed that all alloys met the target properties for base metal Bend tests of welds made in a vacuum purged controlled-atmosphere chamber showed that only the welds in the FS-85 alloy possessed the desired target properties Author

N63-22320 ACF Industries Inc., Albuquerque, N Mex
THE WELDING OF 7000 SERIES ALUMINUM FOR NUCLEAR ROCKET APPLICATIONS
A J Kish In Atomic Energy Commission Proc of Nuc Propulsion Conf, Naval Postgraduate School Monterey Calif Aug 15-17, 1962 p 191-200 (See N63 22301 23-01) OTS $3 00

The weldability of 7000 series aluminum alloy has been investigated by the evaluation of 158 weldments in material 1 4 inch to 3 inches in thickness In addition, twenty 7000 series pressure vessels and cylindrical weldments have been successfully fabricated Welding of the 7000 series aluminum alloys is particularly sensitive to equipment reliability and operator skill Based upon the results of the development program, it may be concluded that 7075 and 7079 aluminum structures can be successfully welded P V E

N63-22728 Lockheed Missiles and Space Co Sunnyvale, Calif
PLASMA JET WELDING, COATING, AND CUTTING: AN ANNOTATED BIBLIOGRAPHY
Scott J Buginas, comp Feb 1963 24 p 68 refs
(SB 63 21)

The search was made in the literature of 1960 to 1962 news-release-type articles were included because of interest in manufacturing applications Author

N63-23028 National Aeronautics and Space Administration Marshall Space Flight Center, Huntsville, Ala
EVALUATION OF WELDED 2219-T87 ALUMINUM ALLOY
Richard A Davis Dec 19 1962 35 p 2 refs
(NASA TM X-50837, MTP-P&VE-M-62-16) OTS $3 60 ph, $1 25 mf

Metal arc inert gas shielded (MIG) welds and tungsten arc, inert gas shielded (TIG) welds were evaluated in plate thicknesses of 1/4, 1/2, 3/4, and 1 inch for aluminum alloy 2219-T87 Studies were conducted to determine the extent of weld heat affected zone into the base metal A value of 1 3/8 inches from the centerline of the weld is given as a maximum extent of heat affected zone if proper joint design and welding process are employed TIG welds were more consistent in strength slightly higher in ultimate strength values, and exhibited better weld quality than MIG welds Author

N63-23470 Aeroprojects Inc West Chester Pa
ULTRASONIC WELDING OF SELECTED REFRACTORY METALS AND ALLOYS Final Report
June 1963 102 p 35 refs
(Contract NOw-61 0410-c)
(Res Rept 63 54)

Investigations with thin gages of molybdenum-0 5% titanium alloy niobium-10% titanium-10% molybdenum alloy and tungsten showed that these materials are susceptible to ultrasonic welding, and that the strength decay of such ultrasonic welds at 2000 F is not appreciably greater than that of the parent sheet material Weld cracking tendencies in some instances were attributed primarily to material contamination, and in other instances to nonuniform material quality It was postulated that improved weld quality can be obtained by strict control of material quality and by the use of programed ultrasonic power and clamping force Author

1964
STAR ENTRIES

N64-10325 Joint Publications Research Service, Washington, D C
ELECTROSLAG WELDING APPLICATIONS
G V Nazarov and Yu N Zaytsev Oct 17, 1963 Transl into ENGLISH of 2 articles from Svarochnoye Proizvodstvo (Moscow), no 8, 1963 p 22-28 refs
(JPRS-21485, OTS-63-31955) OTS $0 50

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1 ELECTROSLAG WELDING OF SHIP PARTS G V Nazarov p 22-25 7 refs

2 ELECTROSLAG WELDING OF PRESS SHAFTS WITH A PLATE ELECTRODE Yu N Zaytsev p 25-28

N64-10750 Joint Publications Research Service, Washington, D C.
BRAZING AND WELDING SINTERED ALUMINUM POWDER
Yu V Dmitriyev et al 18 Mar. 1963 26 p refs Transl. into ENGLISH of two articles from Svarochnoye Proizvodstvo (Moscow), no 11, 1961 p 7-13
(JPRS-18187; O.S-63-21349) OTS: $0 75

Investigations were conducted using sheet material of SAP (sintered aluminum powder). The possibility of obtaining welded bonds of SAP sheets was demonstrated, and the technique for spot welding was developed The technology for the cladding of SAP with various aluminum alloys is described A method for spot and seam welding of SAP sheets was developed; the welded bonds of the clad SAP have high strength at room and at elevated temperatures Results are also presented from investigations on the brazing of SAP materials, using zinc and aluminum solder, by the abrasion, gas flame, and electrocontact methods R T K.

N64-10767 Joint Publications Research Service Washington, D.C
CERTAIN PROBLEMS ON THE WELDING OF METAL POWDERS
L A Mel'nikov *In its* Metal Powders and Welding 1 Apr. 1963 p 1-8 refs Transl. into ENGLISH from Svarochnoye Proizvodstvo, (Moscow), no 11, Nov. 1962 p 13-15 (See N64-10766 02-18) OTS. $0 50

Iron powders of various granulations, as well as powders of tungsten, nickel, tin, lead, titanium, aluminum, and certain ferroalloys were welded. The possibility of welding metallic powders, permitting the creation of a broad range of alloys in the weld seam (including cermets) with extremely varied properties, was demonstrated. The welding of powders was accomplished simultaneously with the process of their being welded to the surface of a metal. R T K

N64-10768 Joint Publications Research Service, Washington, D.C.

POWDER-PLATE ELECTRODE FOR ELECTROSLAG FACING

A Ya Shvartser, I Ya Golub, and G V Lugovava *In its* Metal Powders and Welding 1 Apr 1963 p 9-16 refs Transl into ENGLISH from Avtomat Svarka, (Kiev), no 11, Nov 1962 p 71-76 (See N64-10766 02-18) OTS $0 50

A rigid electrode is described whose casing consists of two plates of sheet steel to which two pieces of electrode wire are welded. The space between the plates is filled with powder. A simple construction of a powder-plate electrode, guaranteeing the alloying of faced material during the electroslag process, was developed. A determination was made of the coefficients of assimilation of a number of alloying elements during the facing of the powder plate. Comparative data were obtained on the current strength during the melting of solid, hollow, and powder-plate electrodes, and the coefficient of fusion of the latter was determined. The powder charge was found to increase the electroconductivity of the plate; this increase depends on the degree of the powder packing. R T K

N64-10770 Joint Publications Research Service, Washington, D C.

ROLE OF ELECTRON BEAM AND ELECTROSLAG REFINING IN SPECIAL WELDMENTS

Ye. Paton and B I. Medovar 2 Apr 1963 11 p refs Transl. into ENGLISH from Avtomat Svarka (Kiev), no. 11, Nov 1962 p 1-7

(JPRS-18490, OTS-63-21474) OTS $0 50

Development of electron beam and electroslag refining processes for improving the quality of steels and alloys in weldments of special uses is discussed. Electron-beam smelting under vacuum, while possessing all the advantages of electroslag remelting (ESR), due to slower sequence of crystallization of liquid metal in a water-cooled metal casting mold, surpasses ESR in such indices as degree of purification from harmful impurities and gases. A promising method of increasing the quality of steels, widely used in welding constructions may be the combination of the electroslag welding process with continuous teeming. In those cases when carbon or alloyed steel is designated for weldments or articles of special designation, preference should be given to ESR, instead of treating liquid metal with synthetic slags P V E

N64-11185 Alloyd Electronic Corp., Cambridge, Mass

A STUDY OF ELECTRON BEAM WELDING Final Summary Report

S S White Watertown, Mass., Watertown Arsenal Labs., Nov 1962 209 p refs

(Contract DA-19-020-ORD-5484)

(WAL-401.54/2-5; AD-407313)

The electron-beam welding gun has been successfully used to effect a nonmelting, postheat treating pass embracing only fusion and high-temperature heat-affected zones. The technique has been applied to five titanium sheet rolling alloys, several types of high-strength steel, molybdenum and molybdenum-1/2 titanium alloy, all in 1/8 in. thickness. Depending on the material and its condition of heat treatment, a postheat treatment can be designed to match fusion zone and base metal in terms of strength, strain, modulus, and impact resistance. For some materials, as-welded properties could be increased in value to above those of the unwelded condition Author

N64-11371 Thompson Ramo Wooldridge Inc Cleveland Ohio

INVESTIGATION OF WELDABILITY OF ADDITIONAL COLUMBIUM ALLOYS [1 Jul. 1962-30 Jun. 1963]

J M Gerken and T L Fullerton Wright-Patterson AFB, Ohio AF Mater Lab Oct 1963 150 p refs

(Contract AF 33(657)-9446)

(ASD TDR-63-843 AD-422025)

The welding characteristics of four columbium alloys, FS-85, B-66, D-36 and Cb-752, in two thicknesses were the subject of this investigation. The effect of tungsten arc or electron beam welding these alloys was to increase the ductile to brittle transition temperature. The increase was greatest for B-66 and Cb-752 and least for D-36 and FS-85. Generally, electron beam welds in a given alloy were more ductile and slightly stronger than tungsten arc welds. Aging tungsten arc welds at 1800° and 2000° F caused an additional increase in transition temperatures. This effect was most pronounced for welds in B-66 and Cb-752 Author

N64-11928 McDonnell Aircraft Corp., St Louis Mo

EVALUATION OF INCONEL 718, AGE HARDENABLE NICKEL-CHROMIUM ALLOY Final Report

Gorman Morris 10 Dec 1963 44 p refs

(Contract AF 33(657)-11215)

(A250, AD-425059)

Tests were conducted to investigate fabrication characteristics of 0 048-in and 0 250-in-thick Inconel 718. Evaluations were made in the following areas: formability (brake forming, uniform elongation in eight inches, and Guerin and impact rubber forming, and dimple forming), resistance welding, fusion butt welding, and TIG spot welding. Room-temperature tensile tests revealed that the mechanical properties were typical for the alloy. Total elongation and uniform elongation tests indicated good formability characteristics of the alloy in the annealed condition. A minimum bend radius of 0 031 in was attained when specimens were bent perpendicular to the rolling direction; a 0 047-in. minimum bend radius was obtained when specimens were bent parallel to the rolling direction. Guerin rubber forming and impact rubber forming methods were used to form 0 048-in specimens on a stretch flange radius of 6 05 in and a shrink flange radius of 9 95 in. The specimens were formed around a 0 090-in bend radius. Both forming methods resulted in formed parts with near production tolerances. Testing on all aged test specimens was ceased at the conclusion of the postweld aging cycle Author

N64-12010 Joint Publications Research Service, Washington, D C

SPOT WELDING OF SINTERED ALUMINUM POWDER WITH D16AT and AMg6 ALLOYS

G F Skakun and A A Chakalev 23 Dec 1963 9 p Transl into ENGLISH of an article from Avtomat Svarka (Kiev), no 8 (125), 1963 p 83-86

(JPRS-22422, OTS-64-21099) OTS $0 50

Experimental electric spot welding of 1- and 1 5-mm-thick plates of SAP with D16AT- and AMg6-type aluminum alloys led to the following conclusions (1) SAP material can be welded satisfactorily with aluminum alloys of the D16AT and AMg6 types (2) Optimal procedures for welding plates 1 and 1 5 mm thick are established that ensure good quality of welded joints, the joints possess sufficient shearing and tensile strength (3) Adhesion of the material to the electrodes is insignificant and permits welding up to 15 to 20 spots without cleaning of the electrodes P V E

N64-12072 Battelle Memorial Inst., Columbus, Ohio Defense Metals Information Center
THE CURRENT STATUS OF THE WELDING OF MARAGING STEELS
R M Evans and R R Monroe 16 Oct 1963 31 p refs
(Contract AF 33(616)-7747)
(DMIC-Memo-182, AD-419383)

Among the various types of maraging steel, the greatest development and evaluation effort has been expended on the 18-percent nickel variety This type combines higher strengths and simpler heat treatments with greater toughness than the other types of maraging steel Carefully designed heat-treatment schedules and cold working of welds in the 25-percent maraging steel have produced strengths equal to that of the base metal, but, the ductility was low. Utilization of the 20-percent nickel alloy suffers from the same difficulties. There is little question that welds with satisfactory strength can be made in 18-percent nickel maraging steels in a wide thickness range. With proper choice of filler-metal composition, welding speed, cleaning procedure, shielding, and other welding variables, porosity-free and crack-free welds are obtained by most commercial welding processes. The fracture toughness of welds in the maraging steels is a subject of considerable concern among users. There appears to be agreement that the fracture toughness of welds in these steels is considerably lower than that of the unaffected parent metal. Author

N64-12647 Aeroprojects Inc., West Chester, Pa
DEVELOPMENT OF ULTRASONIC WELDING EQUIPMENT FOR REFRACTORY METALS Interim Technical Progress Report, Jul.-Sep. 1963
Nicholas Maropis Oct 1963 25 p refs
(Contract AF 33(600)-43026)
(ASD-TR-7-888 (VI), AD-422469)

Design, development, and construction of a 25-kw spot-type welding machine have continued, with emphasis on refining the design of the tension-shell ceramic transducer and coupling systems, analysis of the adequacy of the hydraulic system, and assembly of components onto the welding machine structure. Modifications are being made in the ceramic transducer design to eliminate arcing and overheating at high power inputs and to permit operation at full design power. The power-force programing system has been found to operate satisfactorily, with low response time, and components are being mounted on the welder frame. Final review of the air-hydraulic force system indicates that it should provide adequate force range, response time, and safety of operation. Author

N64-12702 Joint Publications Research Service, Washington, D.C.
SOME FEATURES OF WELDING NIOBIUM AND ITS ALLOYS
D. S Balkovets and L. N. Kaganov 3 Jan. 1964 12 p refs
Transl into ENGLISH from Svarochnoye Proizvodstvo (Moscow), no. 10, Oct. 1963 p 10-12
(JPRS-22597, OTS-64-21205) OTS: $0.50

The results of some investigations on argon arc, spot, and roller welding of niobium alloys and the properties of the welded joints obtained are cited. It was found that a considerable gas content in niobium alloys ($\geq$0.01% O_2 and $\geq$0 02% H_2) substantially lowers the plasticity of joints made by argon arc welding. Vacuum annealing before welding and especially after welding increases the plasticity of the welded joints. In the case of spot and roller welding of niobium alloys, the greatest difficulty lies in the melting of the copper electrodes because of the high melting points of these alloys The use of screens and graphite coating of the welded parts substantially reduces the melting of the electrodes Author

N64-12956* National Aeronautics and Space Administration Goddard Space Flight Center, Greenbelt, Md
ULTRASONIC WELDING OF A BERYLLIUM WINDOW ASSEMBLY
J A Munford, B R Cantor, and A Pitch Washington, NASA, Jan 1964 9 p
(NASA TM X-935) OTS $0 50

A method of fabricating thin beryllium window assemblies in rigid frames by ultrasonic welding of thin (0.001 inch) beryllium foil to AISI 310 stainless steel is described Interleaf rings of 0 001-inch aluminum foil are used between the beryllium and stainless steel for cushioning and to reduce power requirements Vacuum-tight joints were achieved, but metallographic examinations indicate the need for improved beryllium Author

N64-13067* Alcoa Research Labs., Aluminum Co. of America, New Kensington, Pa
WELDABLE HIGH STRENGTH ALUMINUM ALLOYS Literature Survey
W. G. Fricke, Jr., E. G Haney, WA. Anderson, and H Y. Hunsicker 20 Aug. 1963 90 p refs
(NASA Contract NAS8-5452)
(NASA CR-52372) OTS: $8.10 ph, $2.90 mf

Published information on the properties and characteristics of high-strength aluminum alloys was reviewed, with particular emphasis on their qualifications for use in welded cryogenic structures. The available information concerning effects of composition, fabricating, and heat treatment factors on the properties of the different types of alloys was examined to ascertain the most promising avenues for further development. The Al-Zn-Mg type alloys currently under development combine good weldability with fairly high strength and cryogenic temperature notch toughness. The Al-Cu type alloys are also considered to offer possibilities of improvement toward the program objectives. Author

N64-13418 Joint Publications Research Service, Washington, D.C.
SUBMERGED-ARC WELDING OF OT4 TITANIUM-ALLOY PARTS
V. B Voklov (Acad Sci Ukr SSR) and O. A. Maslyukov *In its* Selections on Titanium and its Alloys from Avtomat Svarka 30 Dec. 1963 p 1-7 refs Transl. into ENGLISH of p 33-36 (See N64-13417 05-01) OTS: $0 75

Automatic submerged-arc welding techniques were used to manufacture titanium alloy parts in order to establish an optimum system of welding ring-shaped and longitudinal butt seams of parts. The quality of the welded joints was evaluated, and control assemblies were tested The welding of joints of experimental units (butt-ring and longitudinal) showed that good quality seams were obtained The X-ray radioscopy and investigation of sections cut from the control parts established that the seams contained no flaws The high quality of the welded joints was also confirmed by hydraulic breaking tests of the units R T K

N64-13420 Joint Publications Research Service, Washington, D C.
JOINING TITANIUM BY VACUUM-DIFFUSION WELDING
N F Kazakov, A. P Shishkova, and K. Ye. Charukhina *In its* Selections on Titanium and its Alloys from Avtomat Svarka 30 Dec. 1963 p 17-24 refs Transl into ENGLISH of p 82-86 (See N64-13417 05-01) OTS $0.75

Experiments on joining titanium by vacuum-diffusion welding were conducted under the following system: temperature 800°, 850°, 900°, 1000°, and 1100° C The pressure selected was in the range of 0.25 to 1 kg/mm^2 The duration of the process was 10 sec, 1, 5, 7, and 10 minutes. Tests of samples welded at low temperatures (800° and 850° C) with pressure 0.5, to 0.8 kg/mm^2, and exposure of 1 to 5 minutes, showed that these systems do not guarantee stable results. Most of the samples broke down at the site of the weld. However, a strong joint can be obtained when the exposure time is increased to more than 5 minutes at the same temperatures as well as at higher temperatures. R T K

N64-14811 Aeroprojects Inc., West Chester, Pa.
ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS WITH POWER-FORCE PROGRAMMING Final Report
Nicholas Maropis and John G. Thomas Dec. 1963 115 p refs
(Contract NOw-63-0125-c)
(Res. Rept. 63-66; AD-427997) OTS: $9.60

Equipment was assembled for ultrasonic welding with power-force programing. Preliminary welding of 2024-T3 aluminum alloy and Inconel X-750 showed significant weld strength improvement with power-force programing. Significantly improved weld strengths and lower strength variability were obtained with power-force programed welding of 0.010-in. and 0.013-in. molybdenum-0.5% titanium alloy and with 0.015-in. B-66 niobium alloy. Author

N64-15675 Joint Publications Research Service, Washington, D.C.
WELDING NICKEL AND ITS ALLOYS
K. V. Bagryanskiy and G. S. Kuz'min 28 Jan. 1964 169 p refs
Transl. into ENGLISH of a book "Svarka Nikelya i Yego Splavov", Moscow, Mahgiz, 1963 p 1–164
(JPRS-22945; OTS-64-21415) OTS: $3.00

This book presents basic information on the properties of nickel and certain of its alloys. The most important physicochemical processes and structural changes that occur during the welding of these metals are considered. The construction peculiarities of welded joints of nickel are described. Data are cited on the presently used materials for the welding of nickel articles—compositions of welding wires, electrode coatings, fluxes, etc. The technology of the existing methods of manual and mechanized welding is considered, and the available domestic experience in the preparation of chemical apparatus from nickel and its alloys is generalized. Author

N64-15819 Naval Air Engineering Center, Philadelphia, Pa. Aeronautical Materials Lab.
INVESTIGATION OF SPOT WELDING CHARACTERISTICS OF TITANIUM ALLOYS Ti-5Al-5Zr-5Sn, Ti-7Al-12Zr, AND Ti-8Al-1Mo-1V
Edward J. Fogarty 20 Nov. 1963 30 p refs
(NAEC-AML-1815; AD-424204)

A study of the resistance welding characteristics of titanium alloys Ti-5Al-5Zr-5Sn, Ti-7Al-12Zr, and Ti-8Al-1Mo-1V are reported. Optimum weld schedules were developed for three gage thicknesses of each alloy through a systematic variation of welding parameters. No difficulty was encountered in resistance welding these alloys. Each alloy could be spot welded using a wide range of machine settings without encountering internal weld quality problems. Data are presented on the room and elevated temperature strength of spot welded joints for each thickness of each alloy. Data are also presented on the thermal stability characteristics and the fatigue strength of spot welded joints in each alloy. Author

N64-15980 Lockheed Missiles and Space Co., Sunnyvale, Calif.
FUSION WELDING OF ALUMINUM: AN ANNOTATED BIBLIOGRAPHY [1962–JUN. 1963]
Helen B. Mc Cormick and Peter R. Stromer, comps. Jul. 1963 27 p refs
(SB-63-56; Rept. 8-30-63-2)

This bibliography (62 refs.) has been compiled on the fusion welding of aluminum alloys, with emphasis on references reporting the latest advances in the Tungsten-Inert-Gas (TIG) process using either alternating current or direct current straight polarity. Entries are arranged alphabetically by senior personal author or by journal article title when no author is given. A subject index is included. Author

N64-16859* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
SELECTED WELDING TECHNIQUES Technology Utilization Notes
Hershel M. Nance et al Washington, NASA [Jan. 1964] 31 p
(NASA SP-5003, originally published as NASA SP-501) GPO: $0.30

Welding tools and techniques employed in the welding of aluminum sheet and plate for large single booster tanks are discussed. These tools and techniques are: (1) a seam tracker and proximity control unit that has proven effective in the welding of heavy-gage aluminum, (2) segmented backup bars for welding; (3) a vacuum-type backup bar that facilitates repairs in normally inaccessible locations, (4) a fiber glass tape, for backing up welds, which retains and shapes the molten bead without weld contamination; (5) a clamping tool for fusion welding that holds workpieces in near-perfect alignment, (6) the alignment of large-diameter cylinders maintained by d.c. current straight-polarity tungsten-inert-gas track welding, (7) a guide tip developed for feeding filler wire when welding with inert gas processes; and (8) an improved method of electric arc welding using the sigma technique. I v L

N64-17090 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
WELDING TURBINE COMPONENTS FORMED FROM HEAT-RESISTANT ALLOYS
G. A. Nikolayev *In its* The Working of Heat-Resistant Alloys 26 Nov. 1963 p 178–185a refs (See N64-17076 09-17)

Introducing welded design simplifies the shape of turbine component castings, enables the replacement of components with rolled stock, contributes to high metal economy, reduces the volume of machining, and guarantees higher strength characteristics. The development of efficient welding equipment and methods is considered primary and is emphasized along with the selection of proper turbine materials. C L W

N64-17091 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
AUTOMATIC ARC AND MOLTEN SLAG ARCLESS ELECTRIC WELDING OF HEAT-RESISTANT ALLOYS
B. I. Medovar *In its* The Working of Heat-Resistant Alloys 26 Nov. 1963 p 186–202 refs (See N64-17076 09-17)

Some of the problems encountered in the automatic arc and gas-electric welding of heat-resistant steels and alloys are discussed briefly. A more detailed treatment is given to the technological and metallurgical features of the molten-slag arcless electric welding of these materials with large-section electrodes. C L W

N64-17092 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
INERT-GAS SHIELDED ARC WELDING OF HEAT-RESISTANT ALLOYS
Ye. M. Pronina *In its* The Working of Heat-Resistant Alloys 26 Nov. 1963 p 203–212a refs (See N64-17076 09-17)

Results of a search for a welding procedure, and a study of the properties of welded joints in heat-resistant alloys are given It has been shown by studies and by industrial experience that inert gas shielded arc welding is the most rational method of fusion welding as applied to heat-resistant steels and alloys 0 8 to 3 0 mm thick The principal advantages of this type of welding are high quality of the welded joints. no need for fluxes. a comparatively small zone of thermal influence a comparatively minor warping of the workpieces. broad possibilities of mechanizing and automating the welding process. and the possibility of welding without filler wires. thereby lowering welding cost C L W

N64-17093 Air Force Systems Command. Wright-Patterson AFB. Ohio Foreign Technology Div
WELDING OF MARTENSITIC STEEL
G A Nikolayev and A V Mordvintseva *In its* The Working of Heat-Resistant Alloys 26 Nov 1963 p 213-223a refs (See N64-17076 09-17)

Experiments were conducted to study the formation of inherent stresses and deformations in welding martensitic steel The influence exerted by time on the deformation of welded joints in steel containing 0 2% carbon and 13% chromium was studied Structural stabilization was determined Attempts were made to eliminate deformation after welding by tempering a buildup specimen in a furnace for one hour at various temperatures Resistance to crack formation in the welding process and during aging was was determined A technique of inert-gas shielded arc welding was developed for the purpose of eliminating slagging. obtaining better visual control of the arc. and reducing surface melting of the edges. Tests showed good mechanical properties of the seams that were welded with carbon dioxide shielded arc welding. the residual deformations were approximately equal to the deformations occurring during manual welding. no cracks were detected in the joints C L.W.

N64-17094 Air Force Systems Command. Wright-Patterson AFB. Ohio Foreign Technology Div
RESISTANCE WELDING OF TITANIUM
P L Chuloshnikov *In its* The Working of Heat-Resistant Alloys 26 Nov 1963 p 224-234 refs (See N64-17076 09-17)

The results of studies of spot and seam welding processes for titanium are given. along with the results of mechanical tests of spot- and seam-welded joints in titanium Allowable maximum deviations were established for the parameters of the welding conditions from the nominal values Tensile static strength tests and fatigue tests were conducted on the titanium welded joints Fracture occurred through the around-the-weld zone of the specimens It was established that the failure of a welded spot joint begins at the junction of the sheets in zones of maximum stress concentration The fatigue tests showed that a noticeable reduction in the fatigue limit of welded joint occurs that is not due to change in the properties of the metal. but is chiefly a result of local stress concentration on the periphery of the spot. which is associated with the design of the lapped joint C.L.W.

N64-17211 Battelle Memorial Inst. Columbus. Ohio Defense Metals Information Center
METALS JOINING Review of Recent Developments. 16 May-15 Nov. 1963
R M Evans 29 Nov 1963 3 p refs

The electron-beam welding of the D-14 (Nb) alloy has resulted in butt welds having a 66,000-psi ultimate strength. a 54,000 psi yield strength. and a 6 6% elongation Lap-shear strengths averaged 723 lb/linear in of weld. and were independent of metal thickness. with the failures always occurring in the heat affected zone Corrugated-panel properties were influenced by erratic penetration of the welds Thin tungsten sheet was joined with pure tungsten when a tungsten hexafluoride-hydrogen mixture was directed into the joint area that was heated by conduction to about 1 200° F Fine-grain structure in the joint and an absence of a heat-affected zone appear to be the advantages Significant increases in quenching rate and decreases in the width of the heat-affected zone were obtained by using refrigerated liquid-cooled backup and hold-down bars during the welding of 2014-T6 and 2024-T86 aluminum sheet As a result. joint efficiencies exceeding 90% in 2014-T6 and better than 85% in 2024-T86 were obtained without post-weld solution or aging treatments Aluminum-to-aluminum honeycomb structures can be vacuum brazed at 150° F below the melting temperature of the base material The use of fluxless aluminum silicon material is the key to the process I v L

N64-17572* IIT Research Inst. Chicago. Ill
INTEGRATED WELDING CONTROLS: WIRE FEED – TRAVEL SPEED Jun. 1962-Apr. 1963 [Final Report]
Fred M Freis 1 Jun 1963 22 p
(NASA Contract NAS3-2667. Proj. K267)
(NASA CR-53246) OTS: $2 60 ph. $0 86 mf

The report describes the development of an optimum system of welding controls to integrate travel speed and wire feed in the MIG welding process without monitoring both variables independently. The system must control one variable by hand adjustment. The prototype system is described and shown schematically. Author

N64-17655 Battelle Memorial Inst. Columbus. Ohio
PLASMA WELDING AND CLEANING
H E Pattee. M. D Randall. and D C Martin Huntsville. Ala. Army Missile Command. 24 Feb 1964 68 p refs
(Contract DA-01-021-AMC-203(Z))
(RSIC-123. AD-432808)

Plasma technology. as it applies to joining metals. is reviewed. and the current status of both welding and cathodic cleaning of metals by plasma arc procedures is summarized. In order to produce defect-free welds. with high joint efficiencies in aluminum alloys by TIG welding procedures. very slow welding speeds. or specialized methods. must be used Although application of the plasma arc to joining metals is still largely in the development stage. it appears to be an attractive welding process The plasma arc is constricted whereas the TIG arc is unconfined Because of the constriction. higher temperatures are available in the plasma arc Thus. substantially higher welding speeds can be achieved than with the TIG process The effectiveness of cathodic cleaning has been demonstrated by surface resistivity measurements. Author

N64-17693* IIT Research Inst.. Chicago. Ill
DEVELOPMENT OF WEAVE BEAD TECHNIQUES FOR MULTIPASS VERTICAL MIG WELDING OF ALUMINUM ALLOYS Final Report, 2 May 1962-2 Jun. 1963
John F Rudy et al 6 Aug. 1963 87 p
(NASA Contract NAS8-2676)
(NASA CR-55902. IITRI-B243-13) OTS. $8.10 ph. $2.81 mf

The purpose of this program was to define the parameters of a machine controlled wide-weave technique for performing vertical-up welds in thick aluminum plates. and to develop a machine to perform the automatic weld so defined. To arrive at a welding technique of sufficient latitude that reproducible high quality would be assured. programed oscillation parameters were sought. The first step was to study the techniques of manual welders in performing similar welds. These studies defined oscillation parameters that gave satisfactory welds. A machine to provide these motions was then developed and evaluated as an automatic welding device. Satisfactory welds were made with this machine when simulating the simpler techniques employed successfully by skilled manual welders Author

N64-18748 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div
AUTOMATIC ELECTRIC ARC WELDING OF TITANIUM
S M Gurevich and S V Mishchenko 12 Jul 1963 23 p refs
Transl into ENGLISH from Avtomat Svarka, (Kiev) v 9 no 5 (50) 1956 p 1-12
(FTD-MT-63-31/1+2, AD-434945)

Questions of the technology of electric arc welding of titanium by a nonfused electrode in a steam of inert gas are considered The peculiarities of the automatic welding of titanium under flux are outlined Data concerning structure and mechanical properties of welded seams are given Author

N64-19024 Douglas Aircraft Co, Inc, Santa Monica, Calif Missile and Space Systems Div
WELDABILITY OF 18Ni-9Co-5Mo MARAGING STEEL SHEET
M M Mabry 16 Mar 1964 72 p refs
(SM-44648)

The alloy is easily welded in either the annealed or the heat-treated condition Sound TIG welds can be produced without benefit of preheat or postheat Simple aging treatments resulted in ultimate strengths ranging from 240 ksi to 319 ksi Cold-working or solution-annealing treatments of the weld deposit, followed by aging, improves the mechanical strength Effects of titanium on weld strength were studied Increasing the titanium content in the weld metal improves the weld strength The hot-cracking tendency of the maraging alloy was compared to 4340 steel The maraging steel is less susceptible to hot-cracking The weldments are apparently resistant to cold or delayed cracking. The room temperature net-fracture strength was evaluated by the shallow-crack criterion Author

N64-20015 Joint Publications Research Service, Washington, D C
ELECTROSLAG WELDING
N I Kakhovskiy, Yu N Gotal'skiy, V E Paton and A A Trushchenko 12 May 1964 91 p Transl into ENGLISH of chapter 5 of the book "Tekhnologiya Mekhanizirovannoy dugovoy i elektroshlakovoy svarki" Moscow, 1963 p 244-314
(JPRS-24559 OTS-64-31244) OTS $2 25

This report discusses the following topics (1) the nature of electroslag welding and its merits (2) the variety of electroslag welding and the areas of possible use (3) fluxes and methods of alloying the metal of the seam for electroslag welding, (4) the process of electroslag welding and initial data for selecting the optimum value of its constituents, (5) the preparation of edges and the joining of joints by the electroslag-welding process, (6) the technology of electroslag welding, (7) the electroslag welding of carbon steels, (8) the electroslag welding of alloyed steels, and (9) the electroslag welding of cast iron and other metals I v L

N64-20407 Frankford Arsenal, Philadelphia, Pa Pitman-Dunn Inst for Research
JOINING OF STEEL AND OTHER WEAR-RESISTANT METALS TO ALUMINUM ALLOYS
M S Orysh, I G Betz, and F W Hussey Aug 1963 62 p refs
(FA-M64-8-1, AD-428299)

The joining of steel and other wear-resistant metals to aluminum alloys was investigated by reviewing the literature, investigating arc welding and diffusion bonding, and evaluating pertinent commercial products It was found that 2024 aluminum alloy can be welded to steel that has been coated with either zinc, aluminum, or a silver alloy, provided the welding arc is directed toward the aluminum member of the joint The diffusion bonding process can be used to join 2024 aluminum alloy to silver alloy-coated steel The surface hardness of aluminum alloy plates can be increased through the application of an experimental hard surfacing aluminum alloy or metallized coating Commercial bimetal products in sheet plate or tube form could be used as transition materials
Author

N64-20518 Lockheed Missiles and Space Co Sunnyvale Calif
THERMIT WELDING Selective Bibliography, 1940-1962
Scott J Buginas comp Feb 1963 21 p refs
(SB-63-25, Rept 5-72-63-7)

This bibliography contains 59 selected references on thermit welding from the literature of 1940-1962 The prime interest areas of the search were in joining aluminum by this process and in joining heavy plate Brief abstracts are included with most citations to expand title information Abstracts are arranged in alphabetical order by author's name
Author

N64-20547 Lockheed Missiles and Space Co Sunnyvale Calif
JOINING OF BERYLLIUM AND ITS ALLOYS BY WELDING AND/OR BRAZING. AN ANNOTATED BIBLIOGRAPHY
Jack B Goldman comp Aug 1963 37 p 90 refs
(Contract NOrd-17017)
(SB-63-61)

Intense investigation has been made of the problem of joining beryllium and its alloys either by welding and or brazing during the past 3 years 1960 to 1963 This annotated bibliography is the result of the examination of printed matter for that period as found in the journal and report literature
Author

N64-20655 Joint Publications Research Service, Washington, D C
WELDING OF TITANIUM ALLOYS
M V Poplavko, N N Manuylov, and L A Gruzdeva *In its* Studies in Welding of Titanium and Niobium 8 May 1964 p 1-58 refs Transl into ENGLISH from Russian book "Svarka Tsvetnykh Metallov i Splavov—Sbornik Statey", Moscow, 1961 p 72-110 (See N64-20654 13-17) OTS $1 75

Among the subjects discussed are the following preparation of surfaces for welding, readiness of titanium for welding, certain technologies in use in welding titanium and its alloys, heat treatment of welded parts the influence of aluminum, tin zircon, molybdenum, etc on the properties of welded joints, and the influence of alloys on angles of bend of welded seams A W

N64-20656 Joint Publications Research Service, Washington D C
WELDING OF NIOBIUM BY VACUUM ARC AND ELECTRON BEAM MELTING
Ye I Istomin and Yu P Gumenyuk *In its* Studies in Welding of Titanium and Niobium 8 May 1964 p 59-64 Transl into ENGLISH from Avtomat Svarka (Kiev), no 1, 1964 p 23-27 (See N64-20654 13-07) OTS $1 75

Methods are investigated for welding niobium of varying purity Experiments were conducted on metal by vacuum arc and electron beam melting using cathode ray, argon arc welding, and welding in a chamber with controlled atmosphere The difference in hardness of niobium obtained by vacuum arc and cathode ray melting constitutes 60 to 70 HV in the initial state It is concluded that niobium lends itself to cathode ray melting as well as to argon arc welding A W

N64-20910 Pratt and Whitney Aircraft, East Hartford, Conn
RESEARCH AND DEVELOPMENT OF TITANIUM ROCKET MOTOR CASE. VOLUME III. DEVELOPMENT OF WELDING PRACTICE Final Report

31 Oct 1963 276 p refs
(Contract DA-19 020 ORD 5230)
(WAL 766 2/1 14 PWA 2267, AD 438715)

A program was undertaken to develop a technique to produce welds of a higher quality than previously obtained. Various welding practices were evaluated by bend, smooth, and notched (K_t 8) tensile and tensile G_c testing. In addition, a cyclic test technique was developed that simulated the stresses welds would be subjected to during hydrostatic pressure testing. The various welding practices included electron beam welding and single and multipass TIG (titanium inert gas) welding using various filler materials and welding fixturing. Electron beam welding did not produce a significant improvement in weld toughness and had many disadvantages for the intended application. Multipass welding produced welds with better geometry and lower porosity than single-pass welding. The use of pure titanium rather than parent metal filler wire did not improve the weld quality. The use of copper fixturing rather than steel fixturing was found to effect further improvement in weld geometry and reduction of porosity. Author

N64-22551 Aeroprojects, Inc., West Chester, Pa
DEVELOPMENT OF ULTRASONIC WELDING WITH EMPHASIS ON PRODUCING HERMETIC SEALS Final Summary Report
J Byron Jones, Nicholas Maropis, John G Thomas, and William N Rosenberg Sep 1963 106 p refs
(Contract DA-36-034-ORD-3254-RD)
(RR-61-99, AD-600597)

Uniformly reproducible ultrasonic ring and continuous seam welds of hermetic-seal quality were produced in several alloys of different gages and in various geometries. The delineation of problems relating to high power delivery in a torsional system indicates that specifications for a ring-type welding unit with a 5-kw power-handling capacity, and capable of welding heavy-gage structural aluminum sheet can result. Continuous-seam welds at speeds in excess of 1 ft/min were produced in 0.040- and 0.064-in 2014-T6 aluminum alloy, with and without interleaf, using a 5-kw welding unit. Weld strengths achieved were up to 95% of parent metal strength. Modification can be made to the ultrasonic continuous-seam unit to handle up to 10 kw in continuous operation, producing welds at reasonable rates in 0.080-in sheet. Theoretical and experimental studies delineated impedance-matching requirements for optimum coupling of the ultrasonic energy to the weldment materials. Author

N64-23235* National Aeronautics and Space Administration Goddard Space Flight Center, Greenbelt, Md
WELDED ELECTRONIC MODULE FABRICATION
John C Lyons and David R Dargo Washington, NASA, Jun 1964 13 p
(NASA TN D 2321) OTS $0 50

A pilot facility for the fabrication of welded electronic modules was developed to provide a quick reaction group in the research and development phases of module fabrication, and to determine in detail the requirements in terms of facilities and trained personnel to insure the production of high-quality welded modules. The experience gained in the successful application of the welding technique to modules in Ariel I and Explorer XVIII provided a firm base for using this concept in future spacecraft programs. Author

N64-23881 Lockheed Missiles and Space Co., Sunnyvale, Calif
FUSION WELDING OF MAGNESIUM AND MAGNESIUM ALLOYS An Annotated Bibliography, Jan. 1962–May 1963
Jack B Goldmann and Helen Mc Cormick, comp Jul 1963 32 p refs
(SB 63-52, Rept 4-11 63-3)

Major emphasis of this report is placed upon fusion welding (TIG and MIG processes) of Mg-Li and Mg-Th alloys, 1/4-in minimum thickness, with comparable data on fusion welding by these same processes for specific alloys of magnesium other than Mg-Li and Mg-Th. Physical properties, metallurgy of the weld, and inert gas welding techniques are shown for these alloys, plus any available data on prewelding and postwelding techniques and property changes. Applications include material gages of 1/4 in and over, in a variety of configurations. The bibliography deals with welding techniques and physical metallurgy of Mg-Li alloys, Mg-Th alloys, and Mg alloys other than Mg-Li and Mg-Th, MIG and TIG welding processes for magnesium and its alloys, plus a few references to advances in MIG and TIG welding techniques in general. Author

N64-24095 United Aircraft Corp., Windsor Locks, Conn Hamilton Standard Div
ELECTRON BEAM TECHNIQUES FOR FABRICATION AND ASSEMBLY OF PARTS FOR ELECTRON TUBES Second Quarterly Report, Oct. 1–Dec. 31, 1963
J F Dudenhoefer [1964] 109 p refs
(Contract DA-36-039-AMC-03625(E))
(EBR-133, AD-435516)

The purposes of the program are outlined. The configurations welded and evaluated are tabulated along with the evaluation procedures and results. The results of the machining evaluation are presented. Progress in applying electron-beam processing to electron-tube fabrication is discussed. Author

N64-24258 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div
MOLTEN-SLAG ARCLESS ELECTRIC WELDING OF VT5-1 TITANIUM ALLOY
S M Gurevich, V P Didkovskiy, and N N Tikhov *In its* Autom Welding 29 Mar 1963 p 49–58a refs (See N64-24252 17-18)

Large section components prepared from a titanium alloy were successfully welded by the molten-slag arcless electric welding method. In welding forged pieces with plate electrodes prepared from the titanium alloy, the welded joints are equally as strong as those of the base metal, with satisfactory plasticity and toughness of the joints. To improve welded joints prepared from extruded alloy sections, it was necessary to increase the plasticity and toughness of the blanks. Molten-slag arcless electric welding of different size rings from the titanium alloy was introduced into batch production. G D B

N64-24334 Battelle Memorial Inst., Columbus, Ohio Defense Metals Information Center
A REVIEW OF AVAILABLE INFORMATION ON THE WELDING OF THICK TITANIUM PLATE IN THE USSR
H W Mishler 6 Mar 1964 24 p refs
(Contract AF 33(615)-1121)
(DMIC-MEMO-188; AD-600976)

In the U S S R, thick titanium plate is being welded by processes that normally are not considered for welding titanium in the U S. These are submerged-arc and electroslag welding. Submerged-arc welding is used for joining titanium with thicknesses in the range of 0.08 to about 2 inches. For thicknesses over 2 inches, electroslag welding is used. Author

N64-24352 North American Aviation, Inc., Los Angeles, Calif.
ELECTRON BEAM WELDING OF ONE-HALF INCH THICK MARAGING STEEL

W D Padian, A. Toy, and R Robelotto *In* AFSC Third Maraging Steel Proj Rev Nov 1963 p 43–71 refs (See N64-24351 17-18)

Information is presented on electron beam welding of 250 and 200 grade maraging steel, including welding procedure development, mechanical property test data, and metallurgical evaluation of electron beam welded joints. This test program was conducted to determine procedures for satisfactory electron beam welds in 1/2-in -thick maraging steel, for application to the construction of solid propellant rocket engine cases D.E.W.

N64-24353 Massachusetts Inst of Tech., Cambridge
WELDING OF 18% Ni-Co-Mo MARAGING ALLOYS
R. E Travis and C. M. Adams, Jr *In* AFSC Third Maraging Steel Proj Rev. Nov. 1963 p 73–94 refs (See N64-24351 17-18)

Weldments have been deposited on 18% Ni maraging steel ranging in thickness from 0 065 to 0 500 in. by the electron beam, permanent electrode, and consumable electrode process. The peak temperatures experienced during welding in the heat-affected zone have been determined, and the darkly etching regions have been identified with specific peak temperatures and correlated with microhardness traverses. In addition, uniaxial and biaxial tensile strengths and joint efficiencies have been determined for various welding processes and heat treat cycles. Author

N64-27230* National Aeronautics and Space Administration, Washington, D.C.
BRAZING AND WELDING OF BERYLLIUM [HARTLOTEN UND SCHWEISSEN VON BERYLLIUM]
H. Weik Jul. 1964 29 p refs Transl. into ENGLISH from Metallwiss und Tech., v. 18, no 3, 1964 p 235-243
(NASA-TT-F-9021)

Recent developmental work in the areas of beryllium metallurgy is described. The state of technology of brazing and welding of beryllium is examined. Suitable joints have been obtained as follows: in the case of rods, by butt brazing in a vacuum and by resistance butt brazing at current intensities above 80,000 A/cm^2; and in the case of sheets, by spot brazing and welding and by arc welding. Ultrasonic welding processes for the welding of beryllium sheets to each other as well as to other metals are also described. R.T.K.

N64-27618 Joint Publications Research Service, Washington, D.C.
ELECTROSLAG WELDING OF FORGINGS OF ALLOY VT6
V. P. Didkovskiy, V. F. Grabin, and S. M. Gurevich *In its* Electroslag Welding and Remelting 6 Aug. 1964 p 1–9 refs (See N64-27617 19-17) OTS: $2.00

Ways are studied of increasing plasticity of the buildup metal during electroslag welding of forgings of alloy VT6. An electrode from integrally alloyed titanium alloy AT8 is proposed, which insures equal strength of the joint and the base metal, high plasticity, and tenacity of the seam metal. Also proposed is a composite electrode made of strips of alloys VT1 and VT6. Author

N64-27619 Joint Publications Research Service, Washington, D.C.
ELECTROSLAG WELDING OF LOW ALLOY STEEL 16GS (3N) WITH A THICKNESS OF 50-140 mm
S. V. Yunger and G. N. Gorkunenko *In its* Electroslag Welding and Remelting 6 Aug. 1964 p 10–18 refs (See N64-27617 19-17) OTS: $2.00

Presented are results of an investigation of rational conditions of electroslag welding steel 16GS (3N) Recommendations are given about selection of electrode wire Detailed information is given about mechanical properties of the seam and the seam-adjoining zone Author

N64-27621 Joint Publications Research Service, Washington, D C.
GUARANTEE OF PRECISE DIMENSIONS OF CYLINDRICAL PARTS IN ELECTROSLAG WELDING
I I. Sushchuk-Slyusarenko, V. M. Khrundzhe, and S. Ya. Shekhter *In its* Electroslag Welding and Remelting 6 Aug. 1964 p 24–30 refs (See N64-27617 19-17) OTS: $2.00

Described is a method of assuring exact dimensions of welded articles that will apply during electroslag welding of articles of right-angle section. However, in practice it is often necessary to join parts of other geometrical form—rollers, base rollers of rolling mills, big machine, shafts, and other articles having a cylindrical form in the place of a break. Author

N64-29298 Aeroprojects, Inc., West Chester, Pa.
DEVELOPMENT OF ULTRASONIC WELDING EQUIPMENT FOR REFRACTORY METALS Interim Technical Progress Report, Apr.–Jun. 1964
Nicholas Maropis Wright-Patterson AFB, Ohio, ASD, Jul. 1964 13 p refs
(Contract AF 33(600)-43026)
(RR-64-53; ASD-TR-7-888(IX); ASD-IR-7-888(IX); AD-444988)

The 15-kc, 4.2-kw ceramic transducer assembly incorporating the improvements shown to be necessary during this development effort was evaluated. Its performance was determined by means of an acoustical calorimeter and exceeded the requirements initially established as necessary for joining the several refractory metals and superalloys in thicknesses up to 0.10 inch with the projected 25-kw ultrasonic welding machine. Author

N64-29566* Battelle Memorial Inst., Columbus, Ohio
STUDIES OF HIGH-FREQUENCY WELDING PROCESS Final Summary Report
W. K. Byrne, J. J. Vagi, and D. C Martin 11 Jun. 1963 97 p
(Contract NAS8-2669)
(NASA-CR-58562) OTS: $8.60 ph

To obtain the needed information on the high-frequency welding process, the research was divided into three phases (1) to study and develop the degree of applicability of the high-frequency welding process to space-launch-vehicle materials; (2) to study and develop the adaptability of the process, including necessary power frequencies and travel speeds, to the material thicknesses and configurations required for launch vehicles; and (3) to design tooling configurations as required for the establishment of final tooling parameters for a production system. Each of these program phases is discussed as follows: (1) process characteristics; (2) equipment; (3) materials; and (4) experimental procedures. Author

N64-29567* North American Aviation, Inc, Los Angeles, Calif.
HIGH VOLTAGE ELECTRON BEAM WELDING OF ALUMINUM ALLOYS Final Report
N Klimmek 14 May 1964 98 p refs
(Contract NAS8-11085)
(NASA-CR-58563; NA-64-469) OTS: $8.60 ph

A research and development program conducted to determine the capability and limitations of high-voltage electron-beam welding equipment for joining high-strength aluminum alloys is described Included are the results of studies pertaining to the following areas the effects of high-strength aluminum alloys on a high-voltage electron-beam welding system; thickness limitations for high-voltage electron-beam welding of aluminum alloys, the effect of variations in lens current, travel speed, and cleaning procedure on weld depth-to-width ratio; the welded-aluminum joints; and electron-beam weld metal chemistry Author

N64-30599 Frankford Arsenal, Philadelphia, Pa.
WELDING 214, 356, AND ALMAG 35 CAST ALUMINUM ALLOYS TO 5456 WROUGHT ALUMINUM ALLOY
M. S. Orysh and I. G. Betz Jul. 1964 21 p refs
(R-1726; AD-444513)

Cast 214, 356-T6, and Almag 35 aluminum plate (3/8 in. thick) were welded to wrought 5456 aluminum alloy plate (3/8 in. thick), using the gas tungsten-arc process. Commercial filler metals 4043, 5183, and 5556 were used. Two beads were deposited on both sides of a double vee joint. It was determined by radiography that the weldments were of excellent quality No defects were noted, except for slight tungsten inclusions in one weld. All tensile test specimens, with the reinforcements removed, failed in the cast member. The weldments containing Almag 35 casting yielded the highest tensile properties. Although the joint efficiencies of the 356-T6/5456 weldments were low, the as-welded properties of this combination were approximately equal to the properties of the 214/5456 weldments. The choice of filler metals had little influence on the weldment properties. Author

N64-30933 Thompson Ramo Wooldridge, Inc., Cleveland, Ohio
DEVELOPMENT OF WELDING PROCEDURES AND FILLER MATERIALS FOR JOINING HIGH STRENGTH LOW ALLOY STEELS Technical Documentary Report, Jun. 1963–Jun. 1964
J. M. Faulkner, G. L. Hanna, and J V. Peck Wright-Patterson AFB, Ohio, AF Mater. Lab., Aug. 1964 224 p refs
(Contract AF 33(657)-11229)
(ML-TDR-64-255; AD-605286)

A research program was conducted to develop welding procedures and filler materials for joining a martensitic and a bainitic steel having yield strengths of 180 to 200 ksi with adequate ductility and fracture toughness. The steels selected for this work were HP 9-4-20, a martensitic steel, and AMS 6435 austempered to produce a bainitic structure. Welding procedures were developed for gas tungsten-arc (TIG) and gas metal-arc (MIG) welding HP 9-4-20 plate and sheet material using filler wires of essentially matching compositions. TIG welds in the HP 9-4-20 plate and sheet material possessed excellent strength and ductility with fracture toughness comparable to the unwelded plate and sheet. MIG welds in the HP 9-4-20 plate failed to meet the basic program requirements. Procedures were developed for making MIG and TIG welds in AMS 6435 plate material, which was austempered at 575° F. Welds made at 4 ipm with a 575° F preheat and postheat for 2 hours met the 180-ksi yield-strength requirement. In no instance did the AMS 6435 weld joints meet the basic yield-strength requirement because of a serious loss in heat-affected zone strength due to overtempering. Author

N64-31095 Naval Air Engineering Center, Philadelphia, Pa. Aeronautical Materials Lab.
ELECTRON BEAM BRAZING OF BERYLLIUM
E. F Deesing 27 Jul. 1964 4 p
(NAEC-AML-1997; AD-603192) OTS: $1.00

Eleven filler metals were used in bead tests under vacuum, using a defocused electron beam—high purity Ag, Ag-Cu eutectic alloy, Ag-braze alloy, Ag-sterling alloy, Ag-0.3% Li alloy, Ag-1.0% Be alloy, Ag-5% Al alloy, high-purity Al, Al-12% Si alloy, Zn-Al-Cu alloy, and commercially pure Zn Brazing of beryllium was attempted with those filler metals that appeared to melt and to wet titanium alloy. However, these filler metals exhibited very poor wettability on chemically cleaned beryllium surfaces. The BeO content of the sintered beryllium apparently inhibited the wettability and flow of the filler metals The highly reactive beryllium surface also contributed to the poor wettability by combining with extraneous elements present in the filler metal. It was also concluded that electron-beam heating was not practical for the brazing process because of the intense localized heating effect produced even at low-energy outputs. Other means of heating in vacuum would be more practical. R.L.K.

N64-31258 Universal-Cyclops Steel Corp., Bridgeville, Pa. Refractomet Div.
THE STATE-OF-THE ART OF WELDING OF REFRACTORY METALS
D. J. Seman and F. D. Seaman Jun. 1963 113 p refs
(Contract NOw-63-0043-c)
(AD-421905)

This document includes a literature and industrial state-of-the-art survey of refractory metal welding. The report summarizes the number and types of facilities engaged in refractory metal welding, summarizes the nature of refractory metal welding, and projects the current methods and limitations in terms of future needs. Author

N64-33922* Martin Co., Denver, Colo.
EXPLOSIVE FORMING AND WELDING OF HONEYCOMB SANDWICH MATERIAL
A Ezra, N Ida, R. Agricola, and N Burningham Oct 1964 114 p
(Contract NAS8-5463)
(NASA-CR-59395; NASA-CR-64-36) OTS $4 00 fs, $0 75 mf

A joint design was selected, honeycomb sandwich panels were prepared, and joints were welded and tested A short probe radiographic technique was developed for the nondestructive testing of welded joints An optimum procedure for the explosive forming of composite end-cap segments of honeycomb sandwich panel, using a patented wax-forming process, was established D E W

1965
STAR ENTRIES

N65-10656# Frankford Arsenal, Philadelphia, Pa.
EXPLOSIVE WELDING
H. J. Addison, Jr. May 1964 14 p refs Presented at the Design Eng. Conf. and Show, ASME, Chicago, 11–14 May 1964
(A64-13; AD-448884)

The explosive welding process through released energy from an explosive source was successfully applied in area, spot, and seam welds. The metal members were located between an explosive charge and an anvil with the lower member resting on the anvil. Satisfactorily welded edges, laps, and tee joints were obtained, and a number of metals and alloys in similar and dissimilar combinations were welded together. A tensile-shear strength approaching that of the base metal has been obtained in some metals in seam-welded lap joints. G.G.

N65-10898# Solar, San Diego, Calif
JOINING OF REFRACTORY METAL FOILS Technical Documentary Report, Jul. 1962–Jul. 1963
J W Welty, P J Valdez, C E Smeltzer, Jr, and C P Davis
Wright-Patterson AFB, Ohio, ASD, Jul 1963 205 p refs
(Contract AF 33(657)-9442)
(ASD-TDR-63-799, Pt I, AD 424651)

Standard methods of welding and brazing refractory metal foils (D36, B66, and TZM) are presented Electron beam, tungsten inert gas, resistance, and ultrasonic welding techniques are evaluated Nine selected candidate brazing alloys for these materials were screened by means of T-joint brazements, room-temperature and high-temperature mechanical property tests, and metallographic structure examination. The most promising joining methods for these materials were extended to the fabrication of small honeycomb panels (0 002-in core, 0 010-in face sheets) that were block-shear tested at temperatures between 2000° and 2800° F Author

N65-11122# Du Pont de Nemours (E I) and Co , Aiken, S C Savannah River Lab.
ATTACHING FUEL ASSEMBLY RIB SPACERS BY ELECTRON BEAM WELDING
Lawrence J Scott Jun 1964 46 p refs
(Contract AT(07-2)-1)
(DP-889) OTS, $2.00

Methods were developed for attaching rib-shaped spacers to nuclear fuel elements and housings by means of electron-beam welding Zircaloy ribs of various sizes were welded to the outside of tubes containing metallic uranium fuel Also, ribs were attached to the inside and outside of thin-wall Zircaloy tubes to form fuel element housings Weld quality was judged by examining weld sections and by conducting corrosion and mechanical property tests Full-size ribbed housings were charged to the heavy-water-components test reactor. Author

N65-11740# Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Tecnnology Div.
WELDING OF SAP-1
Yu V Melnikov, V. V. Zyukin, and V. I Oboturov *In its* Aluminum Alloys 25 Aug 1964 p 124–134 (See N65-11724 02-15)

Investigations of welding by fusion and resistance welding of SAP-1 were performed on 1 5-mm-thick sheet samples obtained from pretreated briquettes It was determined that argon arc welding of SAP-1, using flux Af-4A, is possible with the use of high-temperature annealing of briquettes Strength of the welded joints constitutes 95% of the strength of the basic material at room temperature and 70% at 500° C. Roller and spot welding were also found to be possible; the strength of the spot-welded joints was found to be fully satisfactory and equivalent to the strength of welded joints of the high-strength aluminum alloys M.P G

N65-11743# Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
FUSION WELDING OF SAP
G. D. Nikiforov, S. N. Zhiznyakov, E Ya Bazurina, and B I Matveev *In its* Aluminum Alloys 25 Aug 1964 p 154–160 (See N65-11724 02-15)

Ways of avoiding the causes of unsatisfactory arc-welding behavior of SAP-1 were investigated Results indicate the following (1) Weldable SAP sheets are not distended during heating to 900° C for 30 min, have heightened plasticity and high strength at room and high temperatures, and have an Al_2O_3 content between 6.9%, and 10 6%. (2) When the aluminum alloy AMg6 is used as filler wire, the ultimate strength of the welded joints is 24 to 28 kg/mm^2 at room temperature and 5 to 6 kg/mm^2 at 500° C. (3) Mutual dissolution of the basic and filler materials occurs during welding (4) Prolonged soaking of welded joints at 400° and 500° C does not change the ultimate strength at room temperature. M.P.G.

N65-11744# Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div
BUTT RESISTANCE WELDING OF WIRE FROM SAP
V K Ivanov, P V Kishnev, and E Ya Bazurina *In its* Aluminum Alloys 25 Aug 1964 p 161–168 (See N65-11724 02-15)

Studies indicating that a high-quality welded joint may be obtained only by simultaneous melting of both the Al and the Al_2O_3 components of sintered aluminum powder (SAP) are reported Such fusion welding yields satisfactory joints in SAP wire that are able to withstand deformation during drawing An industrial version of the machine used for butt welding by fusion should have arrangements for reliable holding and fast removal of wire of any length, a mechanism for exact centering of the joint, and an attachment for adjusting the secondary voltage in the range from 2 5 to 8 volts M P.G

N65-12854# Battelle Memorial Inst , Columbus, Ohio Defense Metals Information Center
METALS JOINING Review of Recent Developments
R M Evans 13 Nov 1964 4 p refs

Reports on research programs recently completed or in progress in the field of metals-joining technology are briefly summarized The following subjects are included (1) aluminum—fracture toughness of aluminum alloy weldments, repairing foundry defects in aluminum alloy castings, welding cast aluminum to wrought aluminum, and joining aluminum to steel, (2) nickel—resistance welding and fusion welding processes on Rene 41, and production of jet engine and aerospace parts using nickel alloys, (3) refractory metals and alloys—welding techniques for niobium alloys, and (4) steels—welding technology, for high-strength martensitic and bainitic steels, and use of 5Ni-Cr-Mo-V steel for submarine hulls D S G.

N65-13535*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala
WELDING FOR ELECTRONIC ASSEMBLIES
Washington, NASA, Nov 1964 86 p refs
(NASA-SP-5011) GPO HC $0 40, OTS MF $0 75

Space-related welding technology for potential industrial use is presented in the following studies *Fundamentals, Determination of Optimum Parameters, Equipment, Interconnecting and Component Lead Materials, Weld Inspection,* and *Process Control* An annex contains a glossary of welding terms G G

N65-13786# Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
ELECTRODES AND FLUXES FOR ARC WELDING
N B Fishbeyn 23 May 1963 69 p refs Transl into ENGLISH of the book "Elektrody i Flyusy Dlya Dugovoy Svarki" Moscow, Gos. Nauchno-Tekhn Izd Mashinostr Lit , 1961 p 1–62
(FTD-TT-62-1522/1+2; AD-606284)

This popularized text for welders covers electrode production technology and properties of electrodes and fluxes It recounts the history of the development of electrodes and fluxes, describes the influence of electrodes and fluxes on the quality of welded joints, and gives examples of the mechanization of electrode production. R L K.

N65-14267 Aeroprojects, Inc , West Chester, Pa
SEALING OF PROPELLANT CONTAINERS BY ULTRASONIC WELDING
I Koziarski Jun 1964 22p refs
(Contract DA-36-034-AMC-0061A)
(RR-64-41; AD-605394)

Ultrasonic ring welding was used to make elliptical weld closures for propellant containers having an elliptical cross section with a relationship of less than 2 to 1 between the major and minor axis dimensions of the ellipse The original container design was modified to include an 0 015-inch wide flange at its open end Component materials selected were 0 010-inch Type 3003-0 aluminum alloy for the container, and 0 005-inch Type 3003-H19 aluminum alloy for the flat cover The components were ultrasonically cleaned before being welded on a 4-kW 15-kc torsional welder Equipment modifications included a special welding tip and a welding anvil with a positioning recess for the weldment Prior to welding, half of the samples had been filled with calcium chloride, and half with Hercules Pistol Powder Metallurgical evaluation indicated sound bonds, and hermetic sealing was verified by helium-leak and water submersion tests Author

N65-15181 General Motors Corp, Indianapolis, Ind Allison Div

ELECTRON BEAM WELDING—APPLICATIONS AND DESIGN CONSIDERATIONS FOR AIRCRAFT TURBINE ENGINE GEARS

N F Bratkovich, W L Mc Intire, and Robert E Purdy *In its* Allison Res and Eng, Vol No. 4, Fourth Quarter 1964 [1964] p 2-9 (See N65-15180 05-25)

Design improvements made possible by the use of electron beam (EB) welding allow the use of the best functional material for each precision component without the distortion of other welding processes or the use of cumbersome fastening parts. Examples are given of the way in which the use of EB welding can improve the design of such precision turbine components as double helical gears, cluster gears, and shaft gears Basic requirements obtain minimum distortion and good quality are discussed and the processing of EB welded gears is described. It was found in metallurgical examination of EB welds in AMS 6265 material that the hardness in the weld zone is comparable to the parent metal hardness and no localized zones of high hardness are induced. Mechanical properties are comparable to or better than welds made with other fusion welding processes. R L.K.

N65-16116# Universal-Cyclops Steel Corp., Bridgeville, Pa. Refractomet Div

WELDING OF REFRACTORY METALS Final Report, 28 Sep. 1962-30 Apr. 1964

L M. Bianchi, W A Mc Neish, and F D Seaman Jul 1964 240 p

(Contract NOw-63-0043-c)

(AD-608818)

This report presents a study of the effects of welding variables on refractory metals and indicates the degree and magnitude of control of the variables necessary for the improvement of production welds in refractory metals The flexibility of InFab as a large inert atmosphere chamber suitable for welding refractory metals was evaluated The ability of a welder to accomplish out-of-position manual welds in InFab was demonstrated A limited investigation indicated improved resistance welds may be produced by inert atmosphere protection Author

N65-16126# Thompson Ramo Wooldridge, Inc., Cleveland, Ohio. TRW Electromechanical Div.

A STUDY OF WELDS IN COLUMBIUM ALLOY D-43

J.M Gerken 25 Mar. 1964 43 p refs

(TM-3865-67)

The welding characteristics of Du Pont D-43 (X-110) columbium alloy (nominal composition 10%W-1%Zr-0.1%C balance Cb) were investigated. Tungsten inert gas, electron beam and resistance spot welding methods were used. The wrought material was fully ductile to −320° F in the as-received, stress-relieved condition. The 45° bend transition temperature of this material was −140° F for tungsten inert gas welded specimens and −200° F for electron beam welded specimens Application of an oxidation protective coating or addition of filler material caused an additional increase in the transition temperature above the as-welded condition The D-43 welds showed a classical aging reaction when subjected to postweld heat treatment Ductile spot welds were made in this alloy Tensile strength of tungsten inert gas and electron beam welds in the as-welded condition was greater than the base material at 80° F and 2200° F testing temperatures Author

N65-17889# Joint Publications Research Service, Washington, D C

WELDING AUSTENITIC STEELS AND ALLOYS

B I Medovar 3 Mar 1965 143 p Transl into ENGLISH of the book "Svarka Austenitnykh Staley i Splavov" Kiev, 1964 p 3 184

(JPRS-28963, TT-65-30421) OTS $4 00

This textbook presents discussions of the austenitic steels and alloys used in welded structures, the basic features of welding austenitic steels and alloys, and the use of different forms of welding in the production of structures of austenitic steels and alloys Short treatments are also given of quality control of welding materials and weld joints of austenitic steels, welding of chrome-nickel austenitic steels and alloys of various types, the welding of austenitic steels with nonaustenitic, the heat treatment of welded structures and joints of austenitic steels, and the electroslag remelting of austenitic steels and alloys D.E W

N65-18528* North American Aviation Inc., Downey, Calif. Space and Information Systems Div.

BONDING AND WELDING OF DISSIMILAR METALS

Leo F. Gatsek *In* NASA, Washington Transforming and Using Space-Res. Knowledge 1964 p 7-19 refs (See N65-18526 08-34) GPO: HC $0.70; OTS: MF $0.75

Problems encountered in attempting to join dissimilar metals by conventional brazing and welding methods are reviewed. The use of a number of joining methods, the metals joined, and properties of the joints produced are discussed for brazing, diffusion-bonding, TIG welding, resistance welding, soldering, electron-beam welding, percussion stud-welding, ultrasonic welding, and roll-bond joining of aluminum to stainless steel. D.E.W.

N65-19231 Rensselaer Polytechnic Inst., Troy, N Y

JOINING OF HIGH-STRENGTH STEELS

Warren F. Savage *In* Battelle Mem Inst Probl. in the Load-Carrying Appl of High-Strength Steels [1964] p 43-47 (See N65-19226 09-17)

Nominal composition and mechanical properties of quenched and tempered steels, cold-worked stainless steels, precipitation-hardening steels, and maraging steels are tabulated. Also, the welding metallurgy of these four types is discussed. Quenched and tempered steels at high-strength levels can be successfully joined by fusion welding if special care is exercised and the structure can be heat-treated after fabrication The high-strength, cold-worked stainless steels appear to be unsuited to fabrication by any existing welding technique. The precipitation-hardening stainless steels are marginal in ability to achieve the required yield strength levels. The maraging steels offer the greatest promise as weldable high-strength steels, but additional research is required to establish an adequate technology based upon sound welding metallurgical principles. E E.B

N65-19613 Radio Corp of America, Somerville, N. J Electronic Components and Devices Div.

DIODE MOUNTING Final Report

In RCA Camden. N J Microelement Diodes Production Eng Measure Nov 1964 55 p (See N65-19615 09-09)

The feasibility of mounting diodes was demonstrated with a tweezer-type welder, but later investigations led to the development of a gap-welding technique, which offered significant advantages One important operating advantage is the ability to readily observe the welding action under magnification, which was of great help in establishing the desired welding parameters Many types and thicknesses of diode lead materials were evaluated to determine their weldability The best lead materials, in order of preference, are platinum, palladium, nickel, kovar, rodar, dumet, and silver Gold plating of these conductor materials (except platinum and silver) was found to improve results. Author

N65-21206 Joint Publications Research Service, Washington, D. C.

WELDING OF TITANIUM AND ITS ALLOYS

B. A. Galitskiy *In its* Forming and Fabrication of Titanium 18 Mar. 1965 p 52-101 (See N65-21204 11-17) CFSTI: $4.00

Welding of titanium and its alloys is discussed, based on a large accumulation of factual information. Topics considered are argon-arc welding, automatic welding under a layer of flux, electroslag welding, contact welding, methods of control of welded connections, control of external defects by surface inspection, ultrasonic method of defect control, control of airtightness of seams using kerosene test, checking airtightness by helium and halogen leak detectors, and air pressure test of airtightness. J.M.D.

N65-21370# Battelle Memorial Inst., Columbus, Ohio. Defense Metals Information Center

METALS JOINING Review of Recent Developments

R. M. Evans 26 Mar. 1965 4 p refs

The brazing, bonding, and welding of refractory metals, and the welding of high-strength steels are reviewed. Also, the electrodes used for resistance-heated bonding are tabulated. Bonding processes which require only a 20-sec cycle and which produce joints equal in strength to the base metal when coated for oxidation resistance have been developed. The development of a HY 180/210 steel having a Charpy V-notch energy absorption of about 50-ft-lb was shown to be feasible. There is some question whether or not weldments in these alloys will be fracture tough for large flaws and high-stress concentrations. It was also noted that a 5Ni-Cr-Mo-V steel has been developed which meets most of the requirements of a HY 140 steel When this alloy is MIG welded with a 2Mn-2Ni filler metal, good explosion-test results are obtained. Other significant results are reviewed and evaluations tabulated. E.E.B.

N65-21556# Battelle Memorial Inst., Columbus, Ohio. Metals Joining Div.

DEVELOPMENT OF METHODS OF MAKING NARROW WELDS IN THICK STEEL PLATES BY AUTOMATIC ARC WELDING PROCESSES Final Report, 24 Mar. 1962–23 Mar. 1964

J. W. Nelson, M. D. Randall, and D. C. Martin 23 Mar. 1964 68 p ref

(Contract NObs-86424)

(AD-454864)

A new welding method was developed and welding parameter ranges were established for automatically welding thick steel plates in all positions. This process, called Narrow-Gap welding, has been extensively evaluated for application to welding thick HY-80 low-alloy steel plates specifically for use in submarine hull fabrication. Narrow-Gap welds are made by the gas-shielded, consumable-electrode process. The most distinguishing feature of the process is the use of a very narrow, square-butt joint (with approximately 1/4-inch gap between plates) rather than conventional Vee- or U-groove joint preparations normally used for arc welding Two variations of the process one using a single electrode wire and the other using twin wires, have been developed. The twin-wire technique was developed to assure good sidewall fusion despite variations in width of the joint opening Welds have been made in the flat, vertical, and overhead positions using the Narrow-Gap process Author

N65-21569# Joint Publications Research Service, Washington, D. C.

VACUUM DIFFUSION WELDING OF HIGH-MELTING METALLOID COMPOUNDS WITH HIGH-MELTING METALS

L. Ya. Popilov ed. 13 Apr 1965 13 p refs Transl into ENGLISH from the book "Novyye Materialy v Mashinostroyenii" Leningrad, 1964 p 124–134

(JPRS-29550; TT-65-30713) CFSTI $1.00

Investigations were conducted on vacuum diffusion welding of (1) hot pressed carbide samples of titanium, molybdenum, and tungsten with themselves and with the high melting metals molybdenum and tungsten in a vacuum of 10^{-2} to 10^{-3} mm Hg, and (2) carbides of zirconium and niobium with the high-melting metals niobium, tantalum, molybdenum, and tungsten in a vacuum of 10^{-3} mm Hg at varying pressures. All welding was carried out in the temperature range 1300° to 2000° C with holding for 5 to 15 minutes, and the quality of the welded seam was analyzed by metallographic investigation. Titanium carbide did not undergo welding with tungsten. All other investigated substances underwent diffusion welding at comparatively low temperatures in the low vacuum It was found that the melting temperature of the carbide is not the determining factor in the selection of optimal welding conditions, and that the quality of the welded seams depends on the welding temperature and the nature of the substance. G.G.

N65-22705# Joint Publications Research Service, Washington, D. C.

ELECTRON-BEAM WELDING OF CHROMIUM

S. M. Gurevich and G. K. Kharchenko 29 Apr. 1965 8 p refs Transl. into ENGLISH from Avtomat Svarka (Kiev), no 12, Dec. 1962 p 56-59

(JPRS-29812; TT-65-30848) CFSTI: $1.00

The mechanical properties of chromium joints welded by the electron-beam method in a vacuum were investigated. Welding in a chamber with a vacuum of 1 to 2 × 10^{-5} mm Hg resulted in a complete fusion of the edges and gave satisfactorily formed seams. A certain sublimation of the chromium was observed. Comparison with joints welded by electric arc fusion in a chamber with controlled atmosphere, and also by manual welding in argon in free air, showed that a minimum seam width was obtained with electron-beam welding, and that the seam was light colored and showed no oxidation. Microanalysis of all welded seams revealed elongated large grains for all welding methods, however the comparative thickness of the crystallites was less for the electron-beam seam Gas analysis showed that the seams welded by electron beam were the least contaminated by oxygen, nitrogen, and hydrogen Annealing of the welded joints at 600° C decreased the transition point somewhat from the viscous to the brittle state. Vacuum electron-beam welded joints had the lowest temperature of transition into the brittle state, and showed nearly the same strength and plasticity as the base metal. G.G.

1963
IAA ENTRIES

A63-10463
ELECTRON BEAM WELDING OF AIRCRAFT MATERIALS AND COMPONENTS.
H. A. Hokanson and J. W. Meier (United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn.)
(AWS, 43rd Annual Meeting, Cleveland, Ohio, Apr. 9-13, 1962.)
Welding Journal, vol. 41, Nov. 1962, p. 999-1008.
Discussion of the advantages of the electron-beam process in the welding of aircraft materials and components. Materials discussed are: H-11 steel and A70, A110AT, and C120AV titanium alloys. Components welded include control housings, elevon tracks, pressure vessels, and ball bearings.

A63-10464
PRECISION POSITIONING CONTROLS FOR WELDING SATURN SPACE VEHICLES.
W. M. McCampbell and H. N. Nance (NASA, George C. Marshall Space Flight Center, Huntsville, Ala.)
(AWS, 43rd Annual Meeting, Cleveland, Ohio, Apr. 9-13, 1962.)
Welding Journal, vol. 41, Nov. 1962, p. 1009-1013.
Description of precision-positioning controls developed for welding Saturn space vehicles at the Marshall Space Flight Center. The weld-seam-tracking system is discussed, and the use of high- and low-frequency transducers in seam-tracking systems is evaluated.

A63-10465
WELDABILITY OF 18% NICKEL STEEL.
C. E. Witherell (The International Nickel Co., Inc., Bayonne, N. J.) and W. A. Fragetta (Curtiss-Wright Corp., Wright Aeronautical Div., Wood-Ridge, N.J.)
(AWS, 43rd Annual Meeting, Cleveland, Ohio, Apr. 9-13, 1962.)
Welding Journal, Research Supplement, vol. 41, Nov. 1962, p. 481-s-487-s.
Presentation of results of a comprehensive weldability study of the recently developed 18%Ni-8%Co-5%Mo maraging steel. Crack-free welds are made without preheat in fully-hardened plate as heavy as 1 in. thick by the covered electrode, gas metal-arc, and submerged-arc processes. Although the weld and heat-affected zone of heat-treated plate has a hardness, as-welded, of hot-rolled or annealed plate, the heat-affected zone hardness is increased, and the weld is hardened by heating at 900°F for 3 hr.

A63-10466
DIFFUSION BONDING TUNGSTEN.
M. J. Alboni (The Marquardt Corp., Van Nuys, Calif.)
(AWS, 43rd Annual Meeting, Cleveland, Ohio, Apr. 9-13, 1962.)
Welding Journal, Research Supplement, vol. 41, Nov. 1962, p. 491-s-502-s. 33 refs.
Army-sponsored research.
Description of a program aimed at developing optimum bonding techniques for the fabrication of rocket-nozzle assemblies. The objectives of the investigation are to: (1) determine and establish the brazing parameters for joining tungsten below its recrystallization temperature, (2) determine and establish the diffusion techniques to raise the remelt temperature of a brazed joint in excess of 4,000°F, and (3) fabricate a rocket-motor nozzle using the procedures and techniques previously established.

A63-11134
JOINING ALUMINIUM TO MILD STEEL BY ARGONARC WELDING.
D. R. Andrews (College of Advanced Technology, Dept. of Metallurgy, Birmingham, England).
British Welding Journal, vol. 9, Dec. 1962, p. 650-658. 19 refs.
Investigation of dissimilar metal joining using an inert-gas welding technique. Particular concern is given to the production of a reliable welded joint between aluminum and mild steel by means of the argon-arc process. Related literature is briefly reviewed, followed by consideration of theoretical and practical aspects involved. It is shown that, if the mild steel is suitably coated, reliable welded joints can be obtained.

A63-11572
FUSION WELDING OF END CAPS IN BERYLLIUM TUBES.
R. G. Gilliland and G. M. Slaughter (Oak Ridge National Laboratory, Metals and Ceramics Div., Oak Ridge, Tenn.)
(American Welding Society, National Fall Meeting, Dallas, Tex., Sept. 25-28, 1961.)
Welding Journal, vol. 42, Jan. 1963, p. 29-36. 13 refs.
Investigation of the suitability of beryllium as a cladding material for fuel elements in advanced gas-cooled reactor applications. A program to develop procedures for the fabrication of beryllium-clad fuel elements and to evaluate the mechanical properties of these welds is described. A study of the welding parameters which influence the integrity of tungsten-arc welds shows that edge-fusion welding is better than the butt- or plug-type. It is further shown that, in order to eliminate root cracking in the welds, it is necessary to obtain a tight fit at the end cap and tube by tapering the joint. Additional refinements, such as preheating the joint to 1,400°F under a suitable cover gas of argon, reduce the propensity of crack formation and propagation during welding and cooling. The results of an evaluation of seven lots of tubing, produced by different fabrication processes, are discussed.

A63-11573
COMPARISON OF PROCESSES FOR WELDING ULTRA-HIGH STRENGTH SHEET STEELS.
R. E. Travis, C. M. Adams, Jr. (Massachusetts Institute of Technology, Cambridge, Mass.), and V. P. Ardito (Allegheny-Ludlum Steel Corp., Brackenridge, Pa.)
(American Welding Society, National Fall Meeting, Milwaukee, Wis., Oct. 1-4, 1962.)
Welding Journal, Research Supplement, vol. 42, Jan. 1963, p. 9-s-17-s.
Contract No. NOw 60-0417 (FBM).
Description of a test program aimed at the development of practical procedures and evaluation of electron-beam welding of ultrahigh-strength sheet steel for pressure-vessel fabrication. Specific features of the program include the following: (1) determination of the effects of energy input, voltage, and travel speed on peak temperature distribution and fusion-zone shape; (2) comparison of electron-beam and arc welds by metallographic examination and chemical analysis; and (3) evaluation of the strength and ductility of these welds through the use of conventional and

A63-11574
WELDING OF COLUMBIUM-1% ZIRCONIUM.
E. A. Franco-Ferreira and G. M. Slaughter (Oak Ridge National Laboratory, Oak Ridge, Tenn.)
Welding Journal, Research Supplement, vol. 42, Jan. 1963, p. 18-s-24-s.
Experimental investigation of the aging behavior of welds in niobium (columbium) alloys containing 1% by wt of zirconium. Postweld annealing in the temperature range of 1,900° to 2,200°F is found to result in overaging, without apparent embrittlement after subsequent heating at low temperatures. Metallographic examination shows good correlation between (1) annealing time and temperature and (2) amount of precipitate produced. It is found that welds with high oxygen-impurity levels may be prevented from aging by proper annealing treatment, but microcracking is apt to occur in the welding of highly contaminated material.

A63-11989
WELDING AND BRAZING OF SPACE AGE MATERIALS.
H. C. Emerson (Rohr Corp., Chula Vista, Calif.)
(American Society of Metals, Golden Gate Conference, San Francisco, Calif., Feb. 1962.)
IN: Materials Science and Technology for Advanced Applications. Englewood Cliffs, N. J.; Prentice-Hall, Inc., 1962, p. 606-631.
Cursory review of the more commonplace joining processes for the space-age metals from the viewpoint of the manufacturing

engineer. Metallurgical peculiarities of the materials are correlated to equipment and to tooling abilities and limitations. Recent facilities, developments, and techniques for metal joining by high-speed brazing, electron-beam, and ultrasonic welding are discussed.

A63-11994
JOINING OF REFRACTORY METALS FOR SPACE POWER APPLICATIONS.
G. M. Slaughter, C. W. Fox, and R. G. Gilliland (Oak Ridge National Laboratory, Metallurgy Div., Oak Ridge, Tenn.)
(American Society of Metals, Golden Gate Conference, San Francisco, Calif., Feb. 1962.)
IN: Materials Science and Technology for Advanced Applications. Englewood Cliffs, N.J.; Prentice-Hall, Inc., 1962, p. 728-746. 13 refs.
Brief discussion of the developments in welding, brazing, and fabrication techniques of niobium, beryllium, and their alloys. Results of a metallographic survey of the specimens used in heat-treating studies are presented. Several promising brazing alloys which readily wet and flow on niobium (columbium) are tabulated.

A63-12063
REMOVAL OF CONTRACTION CAVITIES IN NIMONIC 75 SPOT WELDS.
D. N. Waller.
British Welding Journal, vol. 10, Jan. 1963, p. 17-23.
Consideration of a new method for the elimination of contraction cavities in spot welds by means of varying postweld heat conditions. A new radiographic technique, which detects the presence of cavities when conventional radiography fails to do so, is described. The thermal expansion and contraction during welding and cooling causes the electrode head to rise and fall. This electrode head movement is recorded and measured in order to compare the rates of cooling produced by the various chosen postheat conditions.

A63-12349
WELDING COLUMBIUM AND COLUMBIUM ALLOYS.
W. N. Platte (Westinghouse Electric Corp., Westinghouse Research Laboratories, Pittsburgh, Pa.)
(American Welding Society, Annual Meeting, 41st, Los Angeles, Calif., Apr. 25-29, 1960.)
Welding Journal, Research Supplement, vol. 42, Feb. 1963, p. 69-s-83-s. 15 refs.
Contract No. AF 33(616)-6258.
Description of the development of a welding technique for pure niobium (columbium) and the development of weldable Nb alloys. Niobium is found to be extremely sensitive to contamination by nitrogen and oxygen. However, nitrogen produces a greater increase in the hardness and ductile-to-brittle transition temperature when contamination occurs during welding. To avoid these changes in properties, welding is done in a closed chamber using an atmosphere of helium, since nitrogen can be removed more easily from helium than from argon. The properties of welds made under pure helium atmospheres are compared with those of welds made under atmospheres contaminated with nitrogen and oxygen. Alloys are designed using weldability parameters based on the physical, mechanical, and metallurgical properties of Nb and its possible alloying elements. The design parameters are used to screen out alloy additions which would produce hot cracking, porosity, loss of ductility at ambient temperatures, and other welding defects. Alloys containing Ti, Mo, W, V, Hf, and Zr are produced, welded, and tested. The alloys are found to be weldable - i.e., not subject to cracking. It is found that weldable alloy additions, with the exceptions of Ti and Hf, increase the ductile-to-brittle transition temperature, while additions greater than 1% decrease it. Alloys containing 10-20% Ti are ductile at liquid-nitrogen temperatures. Data on the hardness and microstructures of the alloys are included. A weld in an alloy of Nb and W, tested in tension at 1,000° and 1,093°C, is found to have strengths comparable to the base material.

A63-12350
WELDING CHARACTERISTICS OF COMMERCIAL COLUMBIUM ALLOYS.
J. M. Gerken and J. M. Faulkner (Thompson Ramo Wooldridge, Inc., Cleveland, Ohio)
(American Welding Society, National Fall Meeting, Milwaukee, Wis., Oct. 1-4, 1962.)
Welding Journal, Research Supplement, vol. 42, Feb. 1963, p. 84-s-96-s.
Contract No. AF 33(616)-7⁻⁻.
Investigation of the weldability of three niobium-base alloys - FS82, D31, and F48. Both gas tungsten-arc and electron-beam welding are included in the study. Welds are evaluated for bend-ductility transition temperature, hardness, tensile strength, and microstructure. The effects of travel speed, shielding-gas composition and purity, filler-metal additions, preheat, and postheat are investigated. Gas tungsten-arc welding is performed in a vacuum-purge atmosphere chamber; however, for comparison, some welds are made without the use of a chamber but with careful back shielding and trailer shielding. Thermal cycles are measured in the fusion and heat-affected zones of gas tungsten-arc welds to help explain mechanical properties and microstructure on the basis of physical metallurgy of each alloy. Tungsten-tungsten rhenium thermocouples are used for measuring the appropriate temperatures. The most significant effect of welding on all alloys investigated is the lowering of ductility or increasing the ductile-to-brittle transition temperature.

A63-12361
ULTRASONICS IN PRODUCTION. I.
Aircraft Production, vol. 25, Feb. 1963, p. 46-52.
Description of some applications of ultrasonics in U.S. industrial practice. Ultrasonic welding, different combinations of materials that have been ultrasonically welded, temperature during welding, clamping force, the wedge-reed system of welding, and the weld strength and plastic deformation of welds are discussed. The advantages of ultrasonic welding methods are indicated. Fluxless soldering and the structural integrity of ultrasonically soldered joints are described.

A63-13422
WELDING PRACTICES FOR BERYLLIUM-COPPER ALLOYS.
E. E. Weismantel, C. F. Cole, and J. A. Butler (Beryllium Corp. Reading, Pa.)
(American Welding Society, Annual Meeting, 43rd, Cleveland, Ohio, Apr. 9-13, 1962.)
Welding Journal, vol. 42, Mar. 1963, p. 207-212.
Brief discussion of the use of beryllium-containing copper alloys in welded structures. The factors most affecting weldability and weldment properties of alloys containing 0.25 to 2.0% beryllium are noted: (1) the refractory oxide formed during welding, (2) weld fluidity; (3) base-metal conductivity; (4) specific heat; and (5) postwelding heat treatment. It is seen that, because of the refractory nature of beryllium oxide, the quality of the welds resulting from multipass operations is influenced partially by the interpass joint preparation and cleaning procedures. The welding of these alloys requires practices similar to those followed in welding materials containing aluminum and titanium as hardening additions. It is shown that because the thermal conductivity and the melting point decrease with increases in beryllium content, the alloys containing more beryllium appear the more readily weldable. Weldment quality and mechanical properties, before and after various thermal treatments, are discussed for several beryllium copper alloys in sheet and plate form. It is found that, where good protective atmosphere is provided, an alloy similar to the base metal can be used as a filler metal. Using the gas tungsten- and metal-arc welding processes and the electron-beam process, little alloying occurs. After postweld thermal treatment, weld metal properties are seen to approach those of the base metal.

A63-13423
RELIABLE WELD JOINT DESIGN FOR HIGH STRENGTH ROCKET MOTOR CASES.
J. R. Dyar and N. F. Bratkovich (General Motors Corp., Allison Div., Materials Joining Laboratory, Indianapolis, Ind.)
(American Welding Society, National Fall Meeting, Milwaukee, Wis., Oct. 1-4, 1962.)
Welding Journal, Research Supplement, vol. 42, Mar. 1963, p. 126-s-133-s.

Presentation of a technical approach for resolving the basic elements of weld design in qualitative and quantitative terms. The approach is based on a statistical study of the stress analysis of welded joints, joint analysis, and filler metal. The stress analysis of the weld joint design is described, and the methods of remedying minor weld defects by reinforcement are considered. The results for various test configurations and for different reinforcements are shown graphically. A 2-in. inside and outside reinforced weld joint, of D6AC base metal, is selected for production applications. Material characteristics and testing methods are described. It is increasingly common. Filament winding finds application in the fabrication of very large rocket cases and cryogenic tankage. Chemical milling, electrochemical machining, and electric discharge machining is tending to displace conventional methods. Numerical production control is achieving a growing place in aerospace production.

A63-13424

THE CRYOGENIC AND ELEVATED TEMPERATURE PROPERTIES OF "SUPER ALPHA" TITANIUM ALLOY WELDMENTS.

D. R. Mitchell and D. L. Day (Titanium Metals Corporation of America, Toronto Ohio).

(American Welding Society, National Fall Meeting, Milwaukee, Wis., Oct. 1-4, 1962.)

Welding Journal, Research Supplement, vol. 42, Mar. 1963, p. 134-s-144-s.

Contract No. NOas 59-6227-c.

Experimental investigation of the properties of weldments of the so-called "Super Alpha" alloys. In this category are Ti-8Al-1Mo-1V, Ti-5Al-5Sn-5Zr, and Ti-7Al-12 Zr. The metallurgical characteristics of these alloys are described, and welding and testing procedures are considered. The mechanical properties are evaluated: (1) longitudinal and transverse weld room-temperature tensile and bend, (2) room-temperature tensile, (3) room-temperature and subzero notch and unnotched tensile, (4) elevated-temperature creep, and (5) stress stability. Results of the tests are given in tabular and graphical form. The properties of each alloy are discussed individually, and then compared with each other. It is seen that good welded properties are exhibited by all the alloys.

A63-14095

ELECTRON BEAM WELDING.

James R. King (Sciaky Bros., Inc., Electron Beam Application, Chicago, Ill.)

Assembly and Fastener Engineering, vol. 6, Mar. 1963, p. 24-29.

Examination of the current status of electron-beam welding. The theoretical aspects are briefly discussed. Electron-beam-welding equipment is described and diagrammed, including the following features: (1) a vacuum chamber, (2) a pumping system to provide and hold proper chamber vacuum, (3) electric controls, (4) motor-driven work carriages, (5) an electron gun, and (6) power supplies. Electron-beam system design for deep-penetration welds is discussed in relation to the special characteristics of the electron beam and the type of weld desired.

A63-14133

EFFECT OF A JOINT GAP ON CRACKING IN HIGH TENSILE C-Mn STEEL.

J. D. Sutherland.

British Welding Journal, vol. 10, Mar. 1963, p. 71-79.

Experimental investigation of the effects of a .0625-in. root gap between high-tensile C-Mn steel members prior to fillet welding. The experimental methods are described. Tests, made with low-hydrogen and rutile-coated electrodes, are discussed, and the results are listed in tables. It is shown that when rapid cooling rates are encountered, there is an increased risk of weld-heat-affected zone cracking in the presence of such a joint gap. It is concluded that a gap reduces the effectiveness of low-hydrogen electrodes as a means of making crack-free welds at rapid cooling rates. Ways of nullifying the deleterious effects of a root gap in fillet joints are outlined.

A63-14303

ADVANCED PRODUCTION.

Irwin Stambler.

Space/Aeronautics, vol. 39, Apr. 1963, p. 84-88.

Survey of recent production techniques that have been developed to accommodate the increased size of missile parts and the miniaturized missile system components. Diffusion bonding and electron-beam welding, and explosive welding techniques are becoming

A63-14324

APPLICATIONS OF THE GAS METAL ARC WELDING PROCESS.

Thomas W. Shearer, Jr.

Engineering Journal, vol. 9, 2nd Quart., 1962, p. 13-16.

Discussion of the application of the arc spot welding and the continous arc welding techniques to the fabrication of light-gage sheet metal. The equipment and principles of the two methods, jointly known as the gas metal arc welding process, are described, and the differences between these essentially similar procedures are pointed out. It is shown that each technique produces a different type of weld. Each method has different merits which determine the applications for which it is suited best.

A63-14447

ELECTRON BEAM WELDING OF LARGE AEROSPACE STRUCTURES WITH PORTABLE VACUUM CHAMBERS.

Gerald V. Anderson (North American Aviation, Inc., Los Angeles, Calif.)

Society of Automotive Engineers-American Society of Naval Engineers, National Aero-Nautical Meeting, Washington, D.C., Apr. 8-11, 1963, Paper 676A. 6 p.

Description of a new concept that permits the electron-beam process to be used for final assembly welding of large production parts. With this concept, 70-ft long production joints are being welded. By using a relatively small portable vacuum chamber that fits on top of the parts to be welded, just the area around the joint is evacuated. Specially designed seals allow the electron gun, mounted on a lid, to slide along the top of the chamber, making 5-ft long runs at speeds up to 60 in./min.

A63-15226

SOLID STATE WELDING OF BERYLLIUM.

E. M. Passmore (Manlabs, Inc., Cambridge, Mass.)

(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)

Welding Journal, Research Supplement, vol. 42, Apr. 1963, p. 186-s-189-s.

Contract No. AF 33(616)-5913.

Investigation of the welding of both (1) hot-pressed and (2) hot-pressed and extruded beryllium powder, using the differential thermal expansion between the beryllium specimens and a molybdenum clamp to hold the adjoining surfaces in contact while induc-

A63-18106

WELDING TITANIUM.

Production Technology, vol. 1, May 1963, p. 74-76.

Discussion of the methods of fusion-welding of titanium. To protect against atmospheric contamination in titanium welds, argon shielding of every heated surface is used. Argon protection of the upper weld-surface and of the weld undersurface is described. Briefly considered are welding cabinets which must be used when complex components make adequate shielding difficult. A schematic diagram of a typical argon-arc welding fixture is presented. Welding equipment, sheet preparation, and the general characteristics of titanium butt welds and fusion welds are discussed. Other methods of joining considered include resistance welding and flash-butt welding. The chief defects in welds, porosity and hardening, are described, and methods for their elimination are outlined.

A63-19329

A STUDY OF WELD HEAT-AFFECTED ZONES IN THE TITANIUM 6Al-6V-2Sn ALLOY.

R. E. Lewis (Lockheed Aircraft Corp., Lockheed Missile and Space Co., Palo Alto, Calif.) and (K. C. Wu (U.S. Army, Watervliet Arsenal, Research and Engineering Division, Industrial Processes Branch, Watervliet, N.Y.).

Welding Journal, Research Supplement, vol. 42, June 1963, p. 241-s-249-s; Discussion, p. 249-s-251-s. 37 refs.

Investigation of high-strength, alpha-beta-type titanium 6Al-6V-2Sn alloy to disclose the properties in weld-heat zones and determine the effect of weld variables and heat treatment on these properties. Results show that the preheat is the most influential factor in retaining toughness in solution-treated-and-aged base metal. Welding without preheat causes severe losses in impact strength and notched tensile strength, which could not be recovered by ageing treatments afterward or by resolution treating and ageing. Mechanisms causing changes in properties are studied by X-ray analysis and photomicrographic techniques.

A63-24201
WELDING OF ELECTRONIC MODULES FOR THE POLARIS MISSILE.
G. Allen and J. Wettstein (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Sunnyvale, Calif.).
IEEE Transactions on Product Engineering and Production, vol. PEP-7, Sept. 1963, p. 1-7.
Investigation of the possibility of welding electronic module. Microwelding is discussed in terms of design and materials problems, and necessary lead dimensions, welding equipment, weld schedules, and quality control. Thousands of welds made and tested offer evidence that nickel, Dumet, and Kovar are weldable lead materials to nickel interconnecting media.

A63-25094
ELECTRON BEAM WELDING TECHNIQUES AS APPLIED TO AEROSPACE STRUCTURES.
Robert Bakish.
SAE Transactions, vol. 71, 1963, p. 112-121. 17 refs.
Review of the properties and generation of electron beams used for welding. Among the areas discussed are tooling for electron beam welding and accomplishments with electron beams in joining aerospace materials, including beryllium, titanium and its alloys, and high-strength steels.

A63-25136
ELECTRON BEAM WELDING.
E. G. Nunn (Edwards High Vacuum, Ltd., Crawley, Sussex, England).
Engineering Materials and Design, vol. 6, Sept. 1963, p. 640-644. 14 refs.
Description of electron-beam welding techniques used for refractory metals, as well as for more common metals, such as stainless steel. Considered are electron-beam machines, guns, and welding techniques. Among the advantages of these techniques are the minimization of atmospheric contamination, the high degree of control of electron-beam power, the very high heat concentration of a beam of electrons on impact, and the fine focus and very low mechanical force of such a beam.

A63-25247
WELDING OF REFRACTORY METALS.
Harry Schwartzbart (ITT Research Foundation, Chicago, Ill.).
IN: HIGH TEMPERATURE MATERIALS. PT. 2. METALLURGICAL SOCIETY CONFERENCES, VOL. 18. Technical Conference, Cleveland, Ohio, Apr. 26, 27, 1961, Proceedings. Metallurgical Society, and American Institute of Mining, Metallurgical, and Petroleum Engineers. Edited by G. M. Ault, W. F. Barclay, and H. P. Munger. New York, Interscience Publishers Div., John Wiley and Sons, Inc., 1963, p. 583-597. 24 refs.
Discussion of the welding techniques used for the refractory metals and their alloys. Successful joining processes include tungsten inert gas, electron beam, resistance spot, flash, ultrasonic, pressure welding, and brazing; special care must be taken with respect to atmospheric contamination, residual stresses, and recrystallization. Generally, niobium and tantalum and their alloys are more readily weldable than molybdenum and tungsten.

1964
IAA ENTRIES

A64-11145
THE BRAZING OF TITANIUM TO ALUMINUM.
F. Bollenrath and G. Metzger (Rheinisch-Westfälische Technische Hochschule, Institut für Werkstoffkunde, Aachen, Germany).
(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)
Welding Journal, Research Supplement, vol. 42, Oct. 1963, p. 442-s-453-s. 53 refs.
Discussion of the problems of brazing the dissimilar metal combination of aluminum-titanium with respect to the metal properties and previous brazing experience. An investigation of the silver-aluminum alloy system showed that, under the conditions prevailing during the experiments, a completely eutectic microstructure was obtained at 33 wt% aluminum. The reactions under simulated brazing conditions between titanium and the materials aluminum and its binary alloys with silver, zinc and silicon were investigated. The strength of the brazed joints of the combination titanium - Al - Mg - Si alloy was also investigated wherein the brazed joint was subjected to the hardening treatment for the Al - Mg - Si alloy. A bend test of lap joints (torch-brazed) of the combinations titanium - aluminum and titanium - Al - Mg - Si alloy with the silver - aluminum filler metal showed that the bend angle, before failure occurred, varied from 40 to greater than 90 degrees. In general, it is found that the influence of the thickness, in the range investigated, of the intermetallic-compound layer on the strength of the brazed joints was of minor significance. It is shown that the form of the test specimen and the brazing process used to have a much greater influence on the strength.

A64-11147
WELDABILITY OF RENE 41.
W. Schwenk and A. F. Trabold (Grumman Aircraft Engineering Corp., Bethpage, N.Y.).
Welding Journal, Research Supplement, vol. 42, Oct. 1963, p. 460-s-465-s.
Brief summary of investigations of the weldability of René 41. Three processes - gas tungsten-arc welding, electron beam welding, and resistance spot-welding - were used to evaluate the weldability of this high temperature nickel alloy. The results of the program indicated that René 41 is a weldable alloy. However, special care should be observed in spot welding this material. The fusion welded base metal possessed high mechanical properties with joint efficiencies exceeding 85%.

A64-11952
RECENT ADVANCES IN ELECTRON BEAM WELDING TECHNOLOGY.
J. W. Meier (United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn.).
(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963.)
Welding Journal, vol. 42, Dec. 1963, p. 963-967.
Review of preliminary tests conducted to determine the welding capabilities of production-type high-voltage electron-beam welding equipment at atmospheric pressure. The welds produced in this manner are evaluated. Results show that welds produced by this process are quite similar to those produced by electron beam welding in a vacuum, and that these welds have excellent properties.

A64-13911
DEVELOPMENT OF WELD FABRICATION TECHNIQUES FOR THE S-IC SATURN V VEHICLE.

D. M. Daley, Jr. (NASA, Marshall Space Flight Center, Huntsville, Ala.) and D. C. Jefferys (Hayes International Corp., Marshall Space Flight Center, Huntsville, Ala.).
(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)
Welding Journal, vol. 43, Jan. 1964, p. 34-41.
Discussion of some of the problems that have been encountered in, as well as welding methods and techniques developed for, the fabrication of the S-IC booster stage of the Saturn V vehicle. In particular, the weld fabrication of the S-IC vehicle is considered. Included is information on material selection, the vertical assembly with soft tooling, and the evaluation of the welding process and equipment for producing high-quality, reliable structures that are a necessity in the giant space vehicles.

A64-13912
WELDING CHARACTERISTICS OF LA141XA MAGNESIUM-LITHIUM ALLOY SHEET.
A. T. D'Annesa and E. Willner (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Sunnyvale, Calif.).
(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)
Welding Journal, Research Supplement, vol. 43, Jan. 1964, p. 1-s - 9-s. 20 refs.
Experimental investigation of the mechanical properties of the gas tungsten-arc welded LA141XA magnesium-lithium alloy. A semiautomatic gas tungsten-arc equipment consisting of a stationary electrode holder and an automatic electrically neutral - i.e., cold wire- filler metal feed assembly is used for welding in this investigation. It is found that inert-gas backing is necessary to avoid the formation of a centerline-rootside oxide-shut. However, the LA141XA alloy can be successfully welded without backside shielding and oxide-shut formation by unconventional techniques. These techniques include chilling the rootside of the joint on a backing fixture, "casting" the weld fusion metal into a backing groove, or formation of unusually large weld fusion zones where sufficient liquid-state occurs. Restraint hot or delayed cracking due to welding does not appear to be a problem with the LA141XA alloy.

A64-14876
RESISTANCE WELDING OF INCONEL 718 NICKEL BASE ALLOY.
W. D. Padian and R. P. Robelotto (North American Aviation, Inc., Research and Development, Metallic Materials Laboratory, Los Angeles, Calif.).
(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)
Welding Journal, Research Supplement, vol. 43, Feb. 1964, p. 49-s-56-s.
Outline of an investigation of the spot and seam welding characteristics of Inconel 718 nickel-base alloy. This wrought material has excellent strength at elevated temperatures ranging from 800 to 1,300°F. The characteristics of the alloy were determined for two material thicknesses and heat treat conditions, and the specimens were evaluated by X-ray and metallographic analysis. The quality, strength, edge distances, and minimum allowable no-shunt spot spacings were the features studied. The results indicate that postweld ageing increases joint properties up to 90% of aged tensile ultimate strength for 0.020 in. material and up to 70% for 0.060 in. material.

A64-15274
WELDING THIN WALLED TITANIUM PRESSURE VESSELS.
G. Pagnotta and G. W. Hume (General Electric Co., Schenectady, N. Y.).
(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963.)
Welding Journal, vol. 42, Sept. 1963, p. 709-714.
Discussion of the gas tungsten-arc process for welding thin-walled titanium pressure vessels. A 0.015-inch-thick wall pressure vessel weighing only 6 pounds is successfully fabricated in a dry box under an argon atmosphere. The welding machine is an ac-dc unit with gas and water controls and maximum current capability of 200 amperes. Welding-grade argon and a lightweight electrode holder with a 2-percent thoriated-tungsten electrode ground to conical shape are employed. The process of degreasing the parts with acetone is described and operation of the dry box is explained. The welding schedule and jigging procedure are described, and results of tensile tests, bend tests, X-ray examinations, and metallographic analysis indicate that the process is capable of meeting established welding requirements. The process is applicable to space vehicle construction where metals of high strength-to-weight ratio must be employed.

A64-15276
BRAZING OF THIN GAGE RENE 41 HONEYCOMB.
L. H. Stone, A. H. Freedman, and E. B. Mikus (Northrop Corp., Norair Div., Materials Sciences Laboratory, Hawthorne Calif.).
(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963.)
Welding Journal, Research Supplement, vol. 42, Sept. 1963, p. 397-s-403-s.
Study of commercial braze alloys for René 41 honeycomb brazing. A Ni-Cr-Si-Mn braze alloy appeared to be the most promising and was subjected to a detailed study. This alloy was also evaluated using a "diffusion sink" concept of brazing to further reduce braze alloy-base interaction. Some of the process parameters established included: amount of braze alloy required for a given panel configuration, method of braze alloy placement, optimum brazing temperatures, and length of time at brazing temperature. The influence of the selected braze alloy, braze cycle, and postbraze heat treatments on the mechanical and metallurgical properties of the base metal as well as the braze joints was determined by short-time tensile and lap shear tests at 600°F and 1850°F, and metallographic analysis. Successful transition from brazing of laboratory honeycomb specimens to full-scale 24 inch to 36 inch production panels using an infrared quartz lamp process was accomplished with minor modification of the laboratory procedures. Presently planned space vehicles will require the use of moderately hot structures in certain areas and René 41 honeycomb brazing can fill this need.

A64-15278
MICROMINIATURE ELECTRON BEAM WELDED CONNECTIONS.
D. J. Garibotti (United Aircraft Corp., Hamilton Standard Div., Electronics Dept., Broad Brook, Conn.) and W. V. Lane (U.S. Army, Electronics Research and Development Laboratory, Fort Monmouth, N. J.).
(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963.)
Welding Journal, Research Supplement, vol. 42, Sept. 1963, p. 417-s-427-s. 5 refs.
Statistical type reliability study of electron-beam joining techniques with associated fixturing used to develop a high termination density interconnection system for the integration of microminiaturized electronic components of the thin film and integrated circuit variety. The interconnecting system is composed of ten stacked wafers. The wafers are joined by means of peripheral conductor ribbons on all four sides, yielding a structure with 80 interwafer conductors and 800 electron-beam welded joints on 0.025 inch centers. The interconnection technique is suitable for application to almost any wafer dimension and geometry. The reliability of the process is measured in terms of mechanical and electrical characteristics of the interconnections which are tested initially and after environmental exposure. Statistical techniques are utilized in the reliability testing of pull strength, weld resistance, thermal shock, ambient temperature range, and vibration. Electron-beam welding is found to be a statistically predictable, exceptionally reliable joining process.

A64-15628
FUSION WELDING OF BERYLLIUM.
E. M. Passmore (Avco Corp., Research and Advanced Development Div., Wilmington, Mass.).
(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)
Welding Journal, Research Supplement, vol. 43, Mar. 1964, p. 116-s-125-s. 24 refs.
Contract No. AF 33(616)-5913.
Investigation of the joining of beryllium (Be) plates by gas tungsten-arc braze welding and fusion welding with ac current, in order to evaluate these techniques for applications at temperatures to 1300°F, and to elucidate some factors affecting weld quality. Braze welds were made using filler strips of an aluminum-12

silicon alloy and of unalloyed silver, arc melted in place. It is found that, although Al-12Si braze welds do not appear to be useful for elevated temperature applications, transverse tensile strengths of Ag braze welds amounting to about 11,000 psi at 1300°F indicate a potential usefulness for such applications. The tendency toward tearing and cracking during fusion welding was found to be reduced by increasing preheat temperature and by decreasing speed and current, as long as comparisons are made between fusion zones of similar size and geometry. Additions of aluminum to the fusion zones in amounts of about 1 percent or less were found to promote tearing. Variations in the susceptibility to tearing encountered in the various lots of Be tested were attributed to variations in the Al content.

A64-16074

SPOT WELDING AGED 16 S. W. G. AND 22 S. W. G. NIMONIC 80A AND NIMONIC 90.

D. N. Waller (British Welding Research Association, London, England).

(British Welding Research Association, Report B4/18/63, Oct. 1963.)

British Welding Journal, vol. 11, Apr. 1964, p. 183-188. 5 refs.

Presentation and evaluation of various methods for removing the tenacious oxide film prior to welding. Spot welding conditions are given for welding aged 16 s.w.g. and 22 s.w.g. Nimonic 80A and Nimonic 90 which enable post service repairs or modifications to be made to aero-engines. Static cross-tension and shear strengths of spot welds made in the aged material are determined and compared with the strengths of welds made in solution treated sheet and with post-weld-aged weld strengths. It is emphasized that careful control of the electrode tip condition during welding must be exercised. Weld current variations (14%) from those recommended will produce low strength welds (50%).

A64-17239

WELDING NICKEL-IRON ALLOYS OF THE INVAR TYPE.

C. E. Witherell (International Nickel Co., Research Laboratory, Bayonne, N. J.).

(American Welding Society, Annual Meeting, 45th, Detroit, Mich., May 4-8, 1964.)

Welding Journal, Research Supplement, vol. 43, Apr. 1964, p. 161-s-169-s. 23 refs.

Study of the welding characteristics of nickel-iron alloys of the Invar type in both sheet and plate thicknesses. Welds produced using filler metal of standard composition were porous and hot cracked. Additions of deoxidants such as manganese and carbon effectively controlled the hot cracking and the porosity was eliminated by the addition of titanium. Sound and ductile welds having properties essentially matching those of the base metal were made using covered electrode and gas shielded processes and a modified filler metal.

A64-17240

IMPROVEMENT OF GAS METAL-ARC SPOT WELDS.

S. A. Agnew and W. N. Canulette (Air Reduction Co., Inc., Air Reduction Sales Co., Process and Equipment Development Dept., Murray Hill, N. J.).

(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)

Welding Journal, Research Supplement, vol. 43, Apr. 1964, p. 184-s-192-s.

Report of an investigation sponsored by NASA to develop suitable equipment and processes for the arc spot-welding of lap joints of aluminum alloy in three different thickness combinations. In a series of 100 consecutive welds, the difference between the minimum and maximum strengths was required to be less than 25% of the average strength of the series. A constant and minimal amount of heat input during arc initiation and a constant thermal conductivity at the joint interface were necessary to meet NASA's requirements. The necessary control of heat input was provided by the use of an electrode retraction system for achieving consistent and rapid establishment of a stable arc at the electrode tip. With the improved heat control, less buckling and more uniform buckling of the top sheet took place, and as a result the variation in thermal conductivity at the interface was reduced. It was found possible to produce welds in excess of NASA's strength requirements, but the variation in strength was greater than that desired, although better than that obtainable with commercial equipment.

A64-17692

INTERCONNECTION TECHNIQUES FOR MICROCIRCUITS.

F. Z. Keister, R. D. Engquist, and J. H. Holley (Hughes Aircraft Co., Culver City, Calif.).

IEEE Transactions on Component Parts, vol. CP-11, Mar. 1964, p. 33-41. 13 refs.

Brief consideration of interconnection techniques for microcircuits, including the materials, processes, and equipment used. The following techniques are discussed: soft soldering; resistance welding; series welding; parallel-gap welding; ultrasonic welding; thermocompression bonding; electroplating, conductive adhesives; deposited films; percussive arc welding; electron beam welding; and laser welding. The two techniques predominately used in today's microcircuitry production are soft soldering and resistance welding.

A64-19180

WELDING OF 18% Ni-Co-Mo MARAGING ALLOYS.

C. M. Adams, Jr. and R. E. Travis (Massachusetts Institute of Technology, Dept. of Metallurgy, Cambridge, Mass.).

(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963.)

Welding Journal, Research Supplement, vol. 43, May 1964, p. 193-s-197-s.

Experimental investigation of the welding of 18% Ni-Co-Mo maraging alloys used in large structures where quench-and-temper heat treatment of assembled components is difficult to accomplish with commercially available heat-treat equipment. Weldments are deposited on 18% Ni maraging steel ranging in thickness from 0.065 to 0.500 in. by the electron beam, permanent electrode and consumable electrode processes. Uniaxial and biaxial tensile strengths and joint efficiencies are determined for the various welding processes and heating cycles. In addition, the peak temperatures experienced during welding in the heat-affected zone are determined, and the darkly etched regions are identified with specific peak temperatures and correlated with micro- and macrostructures. Transverse tensile testing of all weldments solutionized and aged subsequent to welding exhibited joint efficiencies that are of an average value of 96%.

A64-19789

LASER WELDING FOR MICROELECTRONIC INTERCONNECTIONS.

Herman Rischall and James R. Shackleton (Hughes Aircraft Co., Ground Systems Group, Fullerton, Calif.).

(Institute of Electrical and Electronics Engineers, Electronic Components Conference, Washington, D.C., May 5-7, 1964.)

IEEE Transactions on Component Parts, vol. CP-11, June 1964, p. 145-151.

Evaluation of laser welding for the fabrication of interconnecting microelectric assemblies. A ruby laser is employed in this investigation. The ability to join dissimilar materials having thickness differences of the order of 50 to 1 is shown to be possible through the use of a laser. The feasibility of welding to thin films is demonstrated by metallurgical examination of the welded connection. Welds are evaluated by visual inspection, macrosection, and microsection. Preliminary results of substrate studies indicate that unglazed alumina is a satisfactory material for this process.

A64-20667

EXO-FLUX WELDING OF STAINLESS STEEL TYPE ALLOYS.

R. A. Long, R. A. Caughey, and W. Bassett (Telecomputing Corp., Narmco Research and Development Div., San Diego, Calif.).

(American Welding Society, National Fall Meeting, Milwaukee, Wis., Oct. 1-4, 1962.)

Welding Journal, Research Supplement, vol. 43, June 1964, p. 259-s-264-s.

Description of the exo-flux bonding concept, in which "exo" refers to a novel externally applied heating tape which provides localized high-energy heat inputs to the parts to be joined, and "flux" refers to the elemental metal-donating compound (e.g., boron oxide, B_2O_3, which supplies elemental boron). The application of the method to the bonding of PH 15-7 Mo, AM 350, AM 355, and A 286 stainless steels is described, as is the adaptation of overlap fabrication processes to honeycomb sandwich bonding.

A64-20799
DISTORTION CONTROL DURING WELDING OF LARGE STRUCTURES.
J. R. Stitt (R. C. Mahon Co., Detroit, Mich.).
Society of Automotive Engineers and American Society of Mechanical Engineers, Air Transport and Space Meeting, New York, N.Y., Apr. 27-30, 1964, Paper 844B. 8 p.
Members, $0.75; nonmembers, $1.00.
Discussion of distortion problems resulting from the arc welding and subsequent cooling of large structures. The causes of this distortion are discussed, as are methods for anticipating the direction it will take. Some available means of distortion control are described, including preforming before welding and the use of an oxy-gas flame to apply corrective V-shaped heats. The use of distortion control techniques is illustrated and includes application to the fabrication of eight 79-ton, 132-ft-long columns forming part of a destructive test stand for the Marshall Space Flight Center.

A64-21065
DIFFUSION WELDING.
W. A. Owczarski (United Aircraft Corp., Pratt and Whitney Aircraft Div., East Hartford, Conn.).
Society of Automotive Engineers and American Society of Mechanical Engineers, Air Transport and Space Meeting, New York, N.Y., Apr. 27-30, 1964, Paper 849A. 13 p. 28 refs.
Members, $0.75; nonmembers, $1.00.
Review of the salient features and best known applications of diffusion welding. An attempt is made to provide a working definition of this technique, as well as a comprehensive review of the manner in which it has been applied in many industries. A brief account of the important technical features of the process, including the parameters to be dealt with in applying diffusion welding to specific problems, is presented.

A64-21706
ELECTRON BEAM AND LASER TECHNIQUES FOR JOINING.
W. J. Farrell (Sciaky Brothers, Inc., Chicago, Ill.).
IN: MATERIALS SCIENCE AND TECHNOLOGY FOR ADVANCED APPLICATIONS; PROCEEDINGS OF THE GOLDEN GATE MATERIALS CONFERENCE, SAN FRANCISCO, CALIF., FEB. 13-15, 1964. VOLUME 2.
Conference sponsored by the American Society for Metals.
Berkeley, Calif., American Society for Metals, 1964, p. 451-510. 8 refs.
Discussion of electron beam welding, which has become an important tool for aerospace fabrication. The unique characteristics of electron beam welds are said to be related to the purity of the atmosphere in which the weld takes place, and the high power density which is possible to attain, resulting in narrow, deep penetrating welds of high joint efficiency and greatly reduced distortion and warpage. The process is now being applied to micro-circuitry welding, general aerospace fabrication and repair. A new field of application has been opened with the development of very powerful electron beam welders - in the order of 30-kw total power - and of automatic power programming: that of welding heavy fabrications to replace large forgings.

A64-21978
GAS TUNGSTEN-ARC WELDING TECHNIQUES WITH A NEW ELECTRONICALLY CONTROLLED POWER SUPPLY.
F. J. Grist and R. L. Hawkins (Miller Electric Manufacturing Co., Appleton, Wis.).
(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963, Paper.)
Welding Journal, vol. 43, July 1964, p. 598-604.
Description of a less-expensive, sophisticated power supply to enhance commercial acceptance of the welding techniques. A welding machine designed especially for thin-gage base metals was developed. Using the gas tungsten-arc process, high-quality (Mil-T-Specification) spot and seam welds can be produced with excellent consistency and reliability. The equipment is somewhat more complex than the average gas tungsten-arc unit, but is not considered to be so exotic as to be prohibitive to the small commercial operator. Infinitely flexible controls are provided for adjusting to desired current programs. The effect of uncontrollable variables such as line voltage and arc length have been minimized by the constant current characteristics of the power source, and through closed-loop feedback. An arc starting mechanism is included which provides precise and reliable arc initiation at all weld currents.

A64-21979
PROCESS AND DESIGN CRITERIA FOR RESISTANCE WELDING RENE 41.
D. T. Lovell and C. N. Anderson (Boeing Co., Aero-Space Div., Seattle, Wash.).
(American Welding Society, Annual Meeting, 45th, Detroit, Mich., May 4-8, 1964, Paper.)
Welding Journal, Research Supplement, vol. 43, July 1964, p. 307-s-319-s. 6 refs.
Report of a research and development program to (1) develop improved resistance welding techniques, (2) determine the effect of spot and seam weld quality on joint properties, and (3) establish realistic processing controls for resistance welding René 41 for elevated temperature applications. Welding parameters were investigated, and weld quality characteristics were evaluated. Thermal cycling tests were conducted. The best overall welding techniques employed preheat and maintained critical control of the heat buildup. Unequal joint thickness combinations were found difficult to weld, but by use of removable metal shims it was found possible to weld at unequal thicknesses as high as 9:1. Metallurgical studies of René 41 base metal at elevated temperatures were conducted. Based upon results of this work, a spot-welding machine was acquired which proved highly successful. Engineering quality and experimental production process control criteria were established from examination of various weld quality characteristics.

A64-22008
INTERCONNECTION TECHNIQUES FOR MICROCIRCUITS.
F. Z. Keister, R. D. Engquist, and J. H. Holley (Hughes Aircraft Co., Culver City, Calif.).
IN: ANNUAL MICROELECTRONICS SYMPOSIUM ON THE DEVELOPMENT OF MICROELECTRONICS THROUGH MATERIALS INTEGRATION, THIRD, ST. LOUIS, MO., APRIL 13-15, 1964, PROCEEDINGS.
St. Louis, Mo., Institute of Electrical and Electronics Engineers, Inc., 1964, p. V-A-1 to V-A-9. 13 refs.
Description and comparative evaluation of the materials, equipment, and processes involved in the welding and bonding of microcircuitry. Covered are soft soldering; resistance welding; series welding; parallel-gap welding; ultrasonic welding; thermocompression bonding; electroplating; conductive adhesives; deposited films; percussive arc welding; electron beam welding; and laser welding. It is concluded that no one technique is suitable for all applications, although soft soldering and resistance welding, because of their proven reliability, at present predominate. Laser welding and electron beam welding, while still under laboratory evaluation, are seen to offer more long-range potential than other techniques, but require fairly expensive equipment and well-trained personnel.

A64-22075
TECHNIQUES IN THE FABRICATION OF WELDED AND ENCAPSULATED HIGH DENSITY ELECTRONIC PACKAGING. II.
S. Maszy, H. L. Uglione, Jr., A. R. Bell, Jr., and R. Spanholtz (Martin Marietta Corp., Martin Co., Orlando, Fla.).
(Institute of Electrical and Electronics Engineers, International Convention, New York, N.Y., Mar. 23-26, 1964.)
IEEE International Convention Record, vol. 12, pt. 9, 1964, p. 111-119.
Review of a program to develop improved module fabrication methods using encapsulant materials and various methods of resistance welding. Data presented are based on the evaluation of the welding transfer molding and welding of over 1600 modules. Among the results of the study are: (1) all component lead materials were weldable, although lead-tin coated leads are found to be undesirable; (2) specific weld schedules need to be established for each welding machine for each combination of material and size; (3) micromodules can be manufactured with less than 1/2% or 1% rejection rate on an economical basis; (4) encapsulation of micromodules by transfer molding techniques reduces time and manpower considerably; and (5) the hi-tower method of packaging enhances the welding process by its case of fabrication.

A64-23530
ULTRASONICS IN WELDING.
N. A. Ol'shanskii and A. V. Mordvintseva.
IN: ULTRASOUND IN INDUSTRIAL PROCESSING AND CONTROL (SOVIET PROGRESS IN APPLIED ULTRASONICS. VOLUME 1).
Edited by V. F. Nozdreva.
New York, Consultants Bureau Enterprises, Inc., 1964, p. 58-68. 8 refs. Translation.

Experimental investigation of the possible areas of application of ultrasounds in welding and of the development of ultrasonic welding technology and equipment. It is stated that ultrasonics may be applied in welding practice on a much wider scale than indicated in the foreign literature. Ultrasonics is said to have the following potential areas of application in welding: (1) it may be used as a source of energy to weld together both metals and nonmetals in spot welds, seam welds, and butt welds; (2) ultrasounds, combined with conventional contact welding, may simplify the welding process; (3) in arc welding and electroslag welding, the

A64-23756
NEW DEVELOPMENTS IN ELECTRON BEAM WELDING.
J. L. Solomon (Sciaky Brothers, Inc., Chicago, Ill.).
American Society of Mechanical Engineers, Production Engineering, and American Society of Tool and Manufacturing Engineers, Conference and Exposition, Detroit, Mich., Apr. 20-24, 1964, Paper 64-Prod-12. 17 p.
Members, $0.50; nonmembers, $1.00.

Review of the state of the art. In this process, a beam of fast-moving electrons, accelerated to half the speed of light by high potentials, is focused by electrostatic and electromagnetic means to the smallest possible spot size on the surface of the work piece, and its kinetic energy is transformed into heat, which brings the temperature of the work at the localized area to the melting point. The process is carried out in a vacuum chamber and provides particularly narrow welds with depth-to-width ratios of up to 30:1. The process is adapted to thin welds and to welding of refractory metals, readily oxidized metals, and vacuum-melted alloys. Equipment generally used is described. Attempts to weld components too large to go into the vacuum chamber have met with some success and involve use of vacuum seals around the portion of the component to be welded. Dissimilar materials can, under some circumstances, be welded by electron beams. Methods of work-handling are discussed.

A64-24499
JOINING OF REFRACTORY METALS.
A. G. Metcalfe (SOLAR, Research Laboratories, San Diego, Calif.).
IN: THE SCIENCE AND TECHNOLOGY OF TUNGSTEN, TANTALUM, MOLYBDENUM, NIOBIUM AND THEIR ALLOYS; PROCEEDINGS OF THE NATO AGARD CONFERENCE ON REFRACTORY METALS, OSLO UNIVERSITY CENTRE, OSLO, NORWAY, JUNE 23-26, 1963.
Edited by N. E. Promisel.
AGARDograph 82.
Oxford, Pergamon Press, 1964, p. 557-570. 12 refs.

Discussion of the state of the art of the joining of refractory metals for aeronautical applications. Fusion welding adequate for aerospace applications, including electron beam welding, tungsten electrode-inert gas (TIG), and metal electrode-inert gas (MIG), is described in terms of weld composition, atmosphere, fixturing and heat treatment, welding speed, and weld bead contour. Resistance welding and ultrasonic and flash welding are briefly considered. High-temperature brazing of the refractory metals is described, as are reactive brazing and weld brazing. Also delineated are the processes of diffusion bonding and pin joining. It is seen that niobium, tantalum, and moderate-strength alloys of these metals can be welded to give strengths and ductilities approaching those of wrought sheet, by arc, electron beam, and resistance welding. Alloys with restricted solubility for interstitials such as molybdenum and tungsten, plus tantalum and niobium alloys rich in the former metals, become irreversibly embrittled by recrystallization.

A64-24592
BONDING, BRAZING, AND WELDING.
M. D. Davis (Beech Aircraft Corp., Wichita, Kan.), F. L. Edmondson, D. C. Mason, Francis H. Crane, A. E. Unruh (General Dynamics Corp., New York, N.Y.), Arthur N. Kugler (Air Reduction Co., Inc., Air Reduction Sales Co., New York, N.Y.), and Frank R. Swaney (Space Technology Laboratories, Inc., Redondo Beach, Calif.).
IN: TOOLING FOR AIRCRAFT AND MISSILE MANUFACTURE.
Edited by Frank W. Wilson and Walter R. Prange.
New York, McGraw-Hill Book Co., 1964, p. 109-163.

Description of methods of joining metallic and nonmetallic materials. In recent years the availability of strong adhesives of uniform quality and the demands of high-speed flight have caused the replacement of many components of conventional structure by adhesive-bonded components. The primary advantage of adhesive bonding is high strength. It is, however, a precise process, and handling and storage are major problems. Adhesives, honeycomb manufacture, and working procedures are described. Controlled atmosphere brazing is discussed with reference to materials, detail fabrication, preparation assembly, brazing fixtures, atmospheres, pressure application, post-braze operations, and quality control. Welding processes are described, with mention of preheating, post-weld thermal treatment, design considerations, fixture design concepts, and welding fixtures.

A64-24777
RESISTANCE SPOT AND SEAM WELDING FV520S SHEET.
I. F. Squires (British Welding Research Association, London, England).
British Welding Journal, vol. 11, Aug. 1963, p. 394-410. 7 refs.
Ministry of Aviation Contract No. KS/1/0110.

Analysis of the parameters for the resistance spot and seam welding of 0.010-in.-thick and 0.022-in.-thick sheets of FV520S steel used in airframe skins and stiffeners. Welding conditions and strengths are determined. Postweld heat treatment was studied with regard to its effect on the weld strength. The effect on the spot welding conditions of preweld heat treatment was also investigated. Other factors studied are the effect on the spot weld of electrode life and weld pitch, the short-time elevated temperature strength, and methods of reducing indentation on one surface of the sheets being welded.

A64-25141
PRODUCTION APPLICATIONS OF ELECTRON BEAM WELDING.
J. W. Meier (United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn.).
(American Society of Mechanical Engineers, Winter Annual Meeting, Philadelphia, Pa., Nov. 17-22, 1963, Paper 63 - WA-122.)
ASME, Transactions, Series B - Journal of Engineering for Industry, vol. 86, Aug. 1964, p. 280-286.

Description of the operation and application of electron-beam welding techniques. The principles of operation and major advantages of electron-beam welding are reviewed. The latter include low-energy input, precise controllability, and a high-purity welding environment. The applications of this technique are discussed, among them its use for welding blades to turbine wheels, fabricating titanium elevon tracks for aircraft, hermetically sealing micro-relays, and repairing and modifying finish-machined components.

A64-25165
SPOT AND STITCH WELDING OF 18 S.W.G. AND 12 S.W.G. JETHETE M 152 - WELDING CONDITIONS AND WELD PROPERTIES.
P. M. Knowlson (British Welding Research Association, London, England).
British Welding Journal, vol. 11, Sept. 1964, p. 462-481. 7 refs.

Study of procedures for surface preparation and welding of two thicknesses of Jethete M 152, a martensitic stainless steel with possible aircraft engine applications. Welding conditions are evaluated for permissible tolerances, strength, consistency, pitch and edge distance effects, stitch welding, and electrode wear. Spot welds are found to be brittle, and methods for their heat treatment are evaluated metallurgically. Elevated temperature strengths are also determined and compared with sheet strengths. The results of the work are presented in data sheet form.

A64-27300
WELDING 3-1/2 AND 9 PER CENT NICKEL STEELS AND 36 PER CENT NICKEL-IRON ALLOY FOR CRYOGENIC SERVICE.
J. W. Flannery (International Nickel Co., New York, N.Y.) and C. E. Witherell (International Nickel Co., Research Laboratory, New York, N.Y.).
(American Society for Testing and Materials, Annual Meeting, 67th, Chicago, Ill., June 21-26, 1964.)
Materials Research and Standards, vol. 4, Oct. 1964, p. 533-539. 9 refs.
Discussion of general welding techniques, including the use of both commercially available and newly developed filler metals. Other points thought to be important are included, such as properties and treatment of base materials, weld preparation, welding technique, preheating, and postheating. The R-99 filler wire composition is reportedly designed to make possible the submerged arc welding of 3-1/2% nickel steel. The R-100 composition is said to give excellent results as a filler metal for the gas metal arc process and to show promise as a core wire for an improved coated electrode. Other wires considered to show good performance are the nickel-base austenitic filler wires and the modified Invar welding wire. D. H.

A64-28171
TUNGSTEN ARC SPOT AND BUTT WELDING OF A CONTROLLED TRANSFORMATION STAINLESS STEEL.
A. G. Brain.
British Welding Journal, vol. 11, Oct. 1964, p. 531-545. 12 refs. Research sponsored by the Ministry of Aviation.
Experimental investigation of the tungsten arc spot and butt welding of 0.022- and 0.010-in. thick FV520 alloy sheet. The influence of welding parameters on spot size, and the effect of this on mechanical properties in tension and shear are studied. The influence of pre- and post-weld heat treatment on the mechanical properties of spot and butt welds is determined. The alloy under study is found to exhibit good weldability in terms of freedom from hot and cold cracking and the formation of hard and brittle structures in the heat-affected zone. The use of weld backing, as well as of a small-bore nozzle, is essential for spot welding of 0.010 (and of 0.022) in.-thick sheet. The consistency of arc striking is greatest with a gradually tapering electrode. In properly formed welds in single-spot shear and tension specimens, the mechanical properties show a coefficient of variation of 4 to 8% for 0.022-in. sheet, and 5 to 19% for the 0.010-in. sheet. V. P.

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IAA ENTRIES

A65-10181
WELDABLE SUPERALLOYS.
James F. Barker and H. Thomas McHenry (General Electric Co., Cincinnati, Ohio).
Mechanical Engineering, vol. 86, Nov. 1964, p. 62-65.
Discussion of the weldability of current alloy sheets. Nickel-base superalloys are liable to cracking in the zone affected by weld heat in two ways: hot-short cracking, and cracking during heat treatment following welding (strain-age, post-weld, or weld-restraining cracking). The various types of failures are discussed in some detail, and a restrained-weld patch test is described which has shown excellent correlation with shop experience. Various alloys are compared, with an examination of their delayed aging reactions. With reference to alloy development, comment is made that the stronger superalloys are the most difficult to fabricate into welded turbine structures. The effects of substitution of columbium for titanium and aluminum in the nickel-base alloys are considered. René 62 alloy is cited as an example of "tailoring" an alloy for increased weldability and high strength in a specific temperature range. F.R.L.

A65-10377
WELDING ALUMINUM PARTS.
Howard E. Adkins (Kaiser Aluminum and Chemical Corp., Kaiser Aluminum and Chemical Sales, Inc., Skokie, Ill.).
Assembly Engineering, vol 7, Nov. 1964, p. 35-38.
Discussion of the three most commonly employed methods of welding aluminum and aluminum alloy parts: tungsten-arc, inert-gas-shielded welding (Tig); metal-arc, inert-gas-shielded welding (Mig); and resistance spot welding. No attempt is made to describe the processes themselves, rather the aim is to provide a basic understanding of the several factors involved, such as oxide film removal, welding current, cleaning and degreasing, filler wire selection, and electrode tip shaping. Specific suggestions are offered as a guide to good practice with each process. W.M.R.

A65-11161
DEVELOPMENT OF ROLL-WELDED SANDWICH PANELS OF TITANIUM ALLOY.
J. A. Houck, D. N. Williams, R. I. Jaffee (Battelle Memorial Institute, Columbus, Ohio), and M. J. Lowy (Douglas Aircraft Co., Inc., Santa Monica, Calif.).
IN: SOCIETY OF AEROSPACE MATERIAL AND PROCESS ENGINEERS, NATIONAL SYMPOSIUM ON MATERIALS FOR SPACE VEHICLE USE, 6TH, SEATTLE, WASH., NOVEMBER 18-20, 1963. VOLUME 2.
Seattle, Society of Aerospace Material and Process Engineers, 1963. 30 p.
Description of a process for fabricating production-size corrugated sandwich panels of titanium alloys. The panels are bonded by rolling in a pack of mild steel with triangular bar inserts interspaced in the corrugations to provide a matrix material to support the structure during roll bonding. The steel matrix also permits forming into shaped sections with simple and compound curvature as low as 1T. After forming, the iron matrix is removed by acid leaching. For corrugation depths greater than about 4 in., fresh acid is pumped to the bottom of the leach holes by a manifold device. The process also can be conducted to provide edge attachments and ports to be rolled into the panels. The present scale of development is up to 36 x 72-in. panels, but the maximum width and length of panels are limited only by rolling mill capacity. The quality of the roll-welded joint is reported to be excellent. The unit area cost appears to be considerably lower than for alternative methods. (Author) D.H.

A65-11362
A LASER SYSTEM FOR WELDING AND MACHINING AEROSPACE METALS.
Robert A. Kaplan (TRG, Inc., Melville, N.Y.).
IN: NATIONAL ELECTRONICS CONFERENCE, 20TH, CHICAGO, ILL., OCTOBER 19-21, 1964, PROCEEDINGS. VOLUME 20.
Chicago, National Electronics Conference, Inc., 1964, p. 929-933. Contract No. AF 33(657)-8799.
Review of the physical principles involved in energy transfer from a laser beam, and description of the principal laser-beam requirements and of the TRG laser system, with the emphasis on control techniques. Experimental results using the laser welding system are presented. The advantage of laser-beam processes is stated to be the extremely high energy densities and the precise control of the beam size and shape which are available. Because of these advantages, it appears that laser-beam processes will find considerable application in specialized machining and welding operations, involving either extremely high melting-temperature materials, or very small and critical dimensions. M.M.

A65-12099
NEW DEVELOPMENTS IN ELECTRON BEAM TECHNOLOGY.
J. W. Meier (United Aircraft Corp., Hamilton Standard Div., Industrial Products, Windsor Locks, Conn.).
(American Welding Society, National Fall Meeting, San Francisco, Calif., Oct. 5-8, 1964, Paper.)
Welding Journal, vol. 43, Nov. 1964, p. 925-931.

Presentation of techniques in electron-beam welding technology that are claimed to have considerable practical significance. Arcing in the high-voltage gun region, caused by contamination from vapors of the material being welded, particularly aluminum, is prevented by incorporating a bend in the electron-beam optical column of a welding machine. Tests have shown that aluminum alloys such as 6061 and 7079 can be welded at maximum power and low welding speeds over extended periods with absolutely no arcing due to metal-vapor contamination. A second development is the electron-beam welding with 25 kw at 150 kv. Its advantages are the capability of heavier section welding with a single pass and the possibility of welding at higher speeds with narrower fusion and smaller heat-affected zones. Single-pass butt welds at these powers have been made in more than 4 in. of AISI 302 stainless steel and 4 in. of 5083 aluminum alloy. The welds were accomplished at 150 kv and 25 kw with a single pass at 7 ipm and 10 ipm, respectively. Last, recent developments in nonvacuum electron-beam welding are discussed. Data are presented on operating parameters and their effect on welding and on mechanical properties of nonvacuum welds in several materials. The penetration of the weld is found to vary inversely as the atomic number of the protective gas used. The welds formed in this process have been shown to have excellent mechanical properties. T. V. Y.

A65-12100

WELDING ALUMINUM SPACE LAUNCH VEHICLES.

S. A. Agnew, N. E. Anderson, C. R. Felmley, and L. M. Layden (Air Reduction Co., Inc., Air Reduction Sales Co., Process and Equipment Development Dept., Murray Hill and Union, N. J.).

(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963, Paper.)

Welding Journal, vol. 43, Nov. 1964, p. 932-937.

Description of gas tungsten-arc and gas metal-arc processes using soft tooling to weld space vehicles in the launch position. The hard-tool functions of internal support, controlling joint fit-up, distortion, and the solid backing for the weld are accomplished by means of launch-position welding, machining operation, and accurate alignment of parts prior to welding, production of a fused zone which distributes shrinkage stresses equally, and by control of penetration, respectively. The equipment used is discussed and photographs are presented showing the various units used. The joint configuration used to reduce distortion in various plate thicknesses is illustrated. The gas tungsten-arc process is chosen when positive control of penetration, low porosity in the weld, and greater plate thickness are desired, while the gas metal-arc process is chosen when speed of travel is important. T. V. Y.

A65-12101

PLASMA ARC WELDING.

Stanley P. Filipski (Union Carbide Corp., Linde Div., Newark Laboratories, Electric Welding Dept., Newark, N. J.).

(American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963, Paper.)

Welding Journal, vol. 43, Nov. 1964, p. 937-943.

Description of the process and apparatus used. Plasma arc welding can be used advantageously on all metals that would normally be gas tungsten-arc welded except aluminum and magnesium. In the thickness range where keyholing can be obtained, its advantages over the gas tungsten-arc process are increased welding speed, uniform penetration, reduced joint preparation, reduced or eliminated filler-metal requirements, and less sensitivity to arc-length variations. Need for mechanical weld backing is eliminated when the keyholing plasma arc process is used, although gas backing is required to protect the weld underbead. Square butt joints are made in material up to 1/4 in. thick with a single pass. Arc shaping is accomplished by bracketing the main orifice of the arc-constricting nozzle with a pair of auxiliary ports. The torch, controls, and power supply are discussed, with rectifiers being preferred for stability in the latter. This process can be applied to stainless-steel tube welding, circumferential pipe welding, welding of reactive metal compacts, aerospace applications, and thin materials. T. V. Y.

A65-12102

PROGRESS IN WELDING 9% NICKEL STEEL.

C. E. Witherell (International Nickel Co., Inc., Research Laboratory, Bayonne, N. J.) and J. V. Peck (Thompson Ramo Wooldridge, Inc., Cleveland, Ohio).

(American Welding Society, Annual Meeting, 45th, Detroit, Mich., May 4-8, 1964, Paper.)

Welding Journal, Research Supplement, vol. 43, Nov. 1964, p. 473-s to 480-s. 46 refs.

Presentation of the development of steel filler metal which is said to produce sound, ductile, and crack-free, gas-shielded welds in 9% nickel steel. The welds have excellent impact strength at -320°F in both the aswelded and stress-relieved conditions and a yield strength of over 100,000 psi. The filler metal contains about 12.5% nickel, 0.05% carbon, 0.6% manganese with low sulfur, phosphorus, silicon, and oxygen levels. The further addition of about 0.1% titanium permits all-position operation with short-circuiting arc-welding techniques. The filler-metal development is discussed in terms of the effects of the various elements and the methods tried. (Author) T. V. Y.

A65-13260 #

SOME PROBLEMS OF WELDING BY FUSING TITANIUM AND ITS ALLOYS [NEKOTORYE VOPROSY SVARKI PLAVLENIEM TITANA I EGO SPLAVOV].

G. L. Petrov, M. D. Shchipkov, A. I. Lebedev, and A. S. Iazykov.

IN: TITANIUM METAL STUDIES; CONFERENCE ON METALLURGY, METALLOGRAPHY AND USES OF TITANIUM AND ITS ALLOYS [METALLOVEDENIE TITANA; SOVESHCHANIE PO METALLURGII, METALLOVEDENIIU I PRIMENENIIU TITANA I EGO SPLAVOV, 5TH, MOSCOW, USSR, MARCH 1963, TRUDY].

Edited by I. I. Kornilov.

Moscow, Izdatel'stvo Nauka, 1964, p. 273-282. 10 refs. In Russian.

Investigation of oxygen and hydrogen sources of saturat[illegible] welded titanium seams to improve the quality of titanium we[illegible]. The procedure of experimental argon-shielded titanium welding is described in detail. Migration of oxygen and hydrogen at the α- and β-titanium phase boundary is examined. It is found that, depending on the partial pressure of hydrogen in the gaseous phase, and the original hydrogen content in the metal, both decrease and increase in hydrogen content may take place in the welded metal. Highly pure argon is found to provide adequate protection of the molten titanium from hydrogen and oxygen. A calculation method is proposed which yields sufficiently accurate data on residual deformation occurring in titanium alloys during argon-shielded welding. V. Z.

A65-13261 #

TWO-ARC FLUX-SHIELDED WELDING OF SEMIFINISHED PRODUCTS OF MEDIUM AND GREAT THICKNESS FROM TITANIUM ALLOYS [DVUKHDUGOVAIA SVARKA POD FLIUSOM POLUFABRIKATOV IZ TITANOVYKH SPLAVOV SREDNIKH I BOL'SHIKH TOLSHCHIN].

S. M. Gurevich and S. D. Zagrebeniuk.

IN: TITANIUM METAL STUDIES; CONFERENCE ON METALLURGY, METALLOGRAPHY AND USES OF TITANIUM AND ITS ALLOYS [METALLOVEDENIE TITANA; SOVESCHANIE PO METALLURGII, METALLOVEDENIIU I PRIMENENIIU TITANA I EGO SPLAVOV, 5TH, MOSCOW, USSR, MARCH 1963, TRUDY].

Edited by I. I. Kornilov.

Moscow, Izdatel'stvo Nauka, 1964, p. 283-286. In Russian.

Presentation of a new method of two-arc flux-shielded welding for thick titanium alloy products, which is distinguished from other two-arc techniques by the displacement of the electrodes both along and across the seam axis and by the application of a current of 600 to 700 amp. The welding technique is described in detail and the mechanical characteristics of titanium welds obtained are tabulated. The results are rated as entirely adequate. V. Z.

A65-13629

SOME RESULTS OBTAINED WITH ELECTRON BEAM WELDING.

W. P. McGregor.

Machinery, vol. 105, Dec. 16, 1964, p. 1436-1439.

Use of Sciaky electron beam welders to weld tantalum, tungsten, nickel, stainless steel, molybdenum, and other materials. The principles of the electron beam welder are described, and the operation of the diffusion pump vacuum system (which evacuates the system to 10^{-4} torr) is outlined. Externally controlled electromagnetic focusing is used. Dissimilar metals successfully joined include: copper to steel and stainless steel; titanium to aluminum and copper; vanadium to tantalum, zirconium, and stainless steel; and zirconium to stainless steel. Photographs of the welder and photomicrographs of welded parts are included. D.H.

A65-15371
150KV ELECTRON BEAM WELDING MACHINE.
The Engineer, vol. 218, Dec. 18, 1964, p. 1003, 1004.

Description of the large high-voltage electron beam welding machine installed at Bristol Siddeley Engines, Ltd. Manufactured by Carl Zeiss, the equipment offers the operator five degrees-of-freedom of movement of the workpiece, which may weigh up to 500 lb. It has a range of high voltage supply up to 150 kV, and is said to be able to handle any component in the aero engine field which is likely to require welding. A long, parallel seam can be produced which at the point of impact confines metallurgical disturbances to a minimum. Working distances of up to 3 ft are possible. The same gun can be used for a wide range of material thicknesses from about 1-1/2 in. to 0.005 in., by reducing the power at the electron gun. The machine can weld dissimilar metals and materials once considered unweldable, such as Nimonic 115. F.R.L.

A65-15387
NONVACUUM ELECTRON-BEAM WELDING - THE BIG BREAKTHROUGH.
Daniel B. Dallas.
Tool and Manufacturing Engineer, vol. 54, Jan. 1965, p. 65-68.

Description of a recent development in electron beam technology which makes it possible to do some welding jobs in an inert-gas or atmospheric environment, thus eliminating the requirement for prolonged pumpdowns and elaborate tooling. Objectives of continuing laboratory research are to increase the working distance and to obtain more data on welding parameters for different materials. Most of the applications to date have been in the welding of steels: 18-8 stainless, AISI, 4340, René 41, and TZM. Other materials such as SAE 1010, and 4620, Inconel X, 5052 and 2219 aluminum alloys, and copper have been successfully welded. Welding speeds of 10 to 145 in./min have been achieved, and working distances in excess of 1/2 in. have been attained with some metals. Topics discussed are: machine operations, vacuum vs nonvacuum welding, and weld characteristics. D.H.

A65-15430
OPTIMUM DESIGN OF HIGH-POWER SERVOS.
P. M. Lowitt and S. M. Shinners (Sperry Rand Corp., Sperry Gyroscope Co., Great Neck, N.Y.).
Electro-Technology, vol. 75, Jan. 1965, p. 41-47. 5 refs.

Brief review of the effects of load resonances and nonlinear friction in the design of high-power servos, followed by presentation of a method for the optimum design of a nonlinear controller which solves these problems. It is shown that a system having a rate feedback loop in conjunction with acceleration feedback is an optimum configuration for the requirements of a typical satellite tracker with regard to load resonances and nonlinear friction. In addition, analytic techniques utilizing signal flow graphs in conjunction with describing functions for the anticipated nonlinearities are used to analyze a proposed ninth-order tracking system with regard to accuracy and stability. Actual simulated results obtained for this system have been compared with anticipated theoretical results. It is considered that the application of this general approach to the class of systems having low resonant frequencies in the presence of nonlinearities is unlimited. F.R.L.

A65-15476 #
WELDING OF MODERN SPECIAL PROPERTY STEELS.
R. A. Kubli and N. D. Freeman (Union Carbide Corp., Linde Div., Newark Laboratories, Newark, N.J.).
(American Welding Society, Annual Meeting, 44th, Philadelphia, Pa., Apr. 22-26, 1963.)
Welding Journal, vol. 43, Aug. 1964, p. 679-685.

Discussion of welding by application of gas metal-arc and submerged-arc processes to HY-80, commercial quenched and tempered structural steels, and maraging steels. These special-property steels have high strength characteristics and good notch toughness. Welding processes to fabricate them are expected to provide weld metal having good mechanical characteristics "as deposited," and after stress relief or after heat treatment. In the gas metal-arc process, a new filler metal may be required to obtain the mechanical properties desired, and the filler metal can be developed with the assurance that the inert atmosphere of the arc will provide metallurgical cleanliness in the deposit. For submerged-arc welding, the development of a filler metal and composition combination can involve considerably more time and effort. Fabricators often prefer to use the process for thick structural components; however, initial production applications are usually made with the gas metal-arc process. HY-80 is welded today using submerged-arc welding, and gas metal-arc welding with either spray or short-circuiting transfer. Commercial quenched and tempered structural steels can also be welded by all three processes to meet the combined requirements of impact and strength specified for the base plate. Maraging steel (18% nickel), basically a low-carbon iron-nickel alloy to which cobalt, molybdenum, titanium, and aluminum have been added, is presently weldable using the spray transfer gas metal-arc and submerged-arc processes. Comment is made that gas metal-arc welding with short-circuiting transfer is being developed rapidly for out-of-position work. F.R.L.

A65-15477 #
PROPERTIES OF X7000-SERIES ALUMINUM ALLOY WELDMENTS.
A. T. D'Annessa (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Palo Alto, Calif.) and R. E. Friend (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Sunnyvale, Calif.).
(American Welding Society, Annual Meeting, 45th, Detroit, Mich., May 4-8, 1964.)
Welding Journal, Research Supplement, vol. 43, Aug 1964, p. 337-s to 343-s. 10 refs.

Presentation of the results of studies conducted to determine the fusion welding characteristics and the mechanical properties of the X7002, X7006, and X7039 aluminum alloy sheet and plate weldments. Welding was performed with the semi-automatic gas tungsten-arc process using single pass, dcsp, square-butt techniques. The MRD 7-5, X5080, and X5039 filler metal compositions were used to weld the X7002, X7006, and X7039 alloys, respectively. Static tensile properties of base-metal control specimens and weld specimens representing various weld/heat-treat sequences, thicknesses, and test temperatures presented include: (1) base-metal and "T6" as-welded properties at 300°F, room temperature, -110°F, and -320°F for sheet and plate thicknesses; (2) properties of post-weld, artificially aged weldments at 300°F, room temperature, -110°F, and -320°F; and (3) room-temperature properties of post-weld solution-heat-treated and artificially aged weldments. In addition, the effects of natural aging on room-temperature properties are presented for as-welded plus 2, 6, 12, and 16 weeks natural-aging reference points. Discussions of the welding characteristics of the various alloys and intergranular, heat-affect zone ruptures of subzero X7002 tensile specimens are included. (Author) F.R.L.

A65-15984
FABRICATING THE S-IC SPACE BOOSTER.
H. E. Farner and T. R. Rutkay (Boeing Co., New Orleans, La.).
(American Welding Society, Fall Meeting, San Francisco, Calif., Oct. 5-8, 1964.)
Welding Journal, vol. 44, Jan. 1965 p. 29-34.

Discussion of the major S-IC components, together with selected details and subassemblies, with special emphasis on forming, heat treatment, and welding. The major detail parts in the S-IC tanks are cylindrical skin sections, Y-ring transition members, tankhead gores, and tankhead fittings. The large sizes of the tank details led to the use of nonconventional forming methods such as bulge and age forming on the tank gore and skin details, respectively. Likewise, the welding of the long complex tank joints led to the development of revised welding concepts such as the use of square butt-edge preparations and the extensive use of blind overlap welding from two sides. Innovations in the fitting-to-gore weldments, the fuel suction elbow, and the LOX tunnels are also described. A. B. K.

A65-15985
PIGMA WELDING - A METHOD FOR REDUCING WELD POROSITY.
R. B. Barker (Dow Chemical Co., Rocky Flats Div., Golden, Colo.).
(American Welding Society, Fall Meeting, San Francisco, Calif., Oct. 5-8, 1964.)
Welding Journal, Research Supplement, vol. 44, Jan. 1965, p. 1-s-6-s.
AEC Contract No. AT (29-1)-1106.

Description of an innovation developed for the purpose of reducing porosity when welding aluminum by the gas metal-arc technique. This innovation, called PIGMA, or Pressurized Inert Gas Metal Arc welding process, consists in regulating the ambient atmospheric pressure of the inert gas shield surrounding the welding arc, in addition to optimizing all of the standard welding variables. A total of 32 welds was made with the equipment described. These welds were divided into four groups, the first two groups being made in an argon-50 v/o helium atmosphere, the third group in an argon atmosphere, and the fourth group in helium. From a radiographic examination it was found that, as the chamber atmosphere was increased, weld porosity decreased, regardless of the gas composition. In helium, porosity varied from 2.75 v/o at atmospheric pressure (12 psia) to 0.1 at 200 psia. In argon, porosity ranged from 6.75 v/o at atmospheric pressure to 0.2 v/o at 200 psia. In the two argon-50 v/o helium mixtures, porosity varied from 3.5 v/o at atmospheric pressure to 0.5 v/o at 100 psi. A. B. K.

A65-15986
ELECTRON BEAM WELDED HEAVY GAGE ALUMINUM ALLOY 2219.
M. W. Brennecke (NASA, Marshall Space Flight Center, Manufacturing Research and Technology Div., Manufacturing Engineering Laboratory, Huntsville, Ala.).
(American Welding Society, Annual Meeting, 45th, Detroit, Mich., May 4-8, 1964.)
Welding Journal, Research Supplement, vol. 44, Jan. 1965, p. 27-s-39-s. 24 refs.

Considerations of characteristics of aluminum alloy 2219. Mechanical properties obtained for electron-beam welded aluminum alloy 2219 vary with welding parameters, thickness of metal, or weld depth-to-width ratio and type of specimen tested. Joint efficiencies up to 80% of tensile strength and 88% of so-called "yield strength" have been obtained for 2219-T87 plate up through 2-3/8 in.-thickness. Satisfactory square butt joints may be welded in the flat or vertical positions employing about the same weld settings or parameters. Variation in parameters in either position can affect resultant strength. Just as in gas tungsten-arc or gas metal-arc welding, maximum strength is associated with high-speed welding when employing the electron beam and lower strength with slower speeds, in which case heat soaks into the base metal and the advantage of the high-energy density of the electron beam is lost. (Author) A. B. K.

A65-16792
ULTRASONIC WELDING.
Charles Zglenicki (U.S. Army, Picatinny Arsenal, Dover, N.J.).
Product Engineering, vol. 36, Feb. 15, 1965, p. 87-91.

Description of a welding technique which makes it possible to join dissimilar materials of widely different thicknesses. Ultrasonic welding combines pressure and high-frequency vibratory motions to create a solid-state bond. No heat is needed. The relationship between ultrasonic welding, on the one hand, and fusion welding, resistance welding, electron-beam welding, and cold-pressure welding, on the other, is examined, and the advantages of ultrasonic welding are pointed out. Although virtually all combinations of dissimilar metals can be welded, best results are obtained with combinations of similar hardness. Generally, all thermoplastics can be bonded ultrasonically, but not thermosetting plastics. Ultrasonic welding of ceramics is still in the laboratory stage. The thickness that can be welded depends primarily on the power of the welding equipment and the area of the weld. Ultrasonic spot welding, seam welding, and ring welding are described. A. B. K.

A65-17423
HANDBOOK OF ELECTRON BEAM WELDING.
R. Bakish and S. S. White (Dynatech Corp., Cambridge, Mass.).
New York, John Wiley and Sons, Inc., 1964. 269 p.
$11.50.

This handbook is considered a self-contained reference work for welding, metallurgical, and mechanical engineers concerned with the application of electron beams to welding. It stresses the achievements of the technique to date and the expectations for electron-beam joining technology in the future. Of the nine chapters composing the discussion, the first two are concerned with the history and fundamental principles of electron beam guns and design parameters. There follows a review of both custom and commercially designed electron-beam joining equipment. These chapters provide a background for the discussion of the physical metallurgy of this type of welding. Jigging and fixturing for electron beam welding, joint designs, and costs are discussed in succeeding chapters, and the last three chapters are concerned with electron-beam application in general, welding standards, and the future of the technology. References are cited at the end of each chapter, and a subject index is presented. F. R. L.

A65-19264
WELDED ALUMINUM PARTS.
Fred R. Collins (Aluminum Company of America, Alcoa Research Laboratories, Process Metallurgy Div., New Kensington, Pa.).
Machine Design, vol. 37, Mar. 4, 1965, p. 128-133.

Description of various welding methods and filler materials for welding aluminum alloys. Commercial welding processes noted include gas metal-arc, gas tungsten-arc, resistance-spot (seam), ultrasonic, pressure, flash, and gas metal-arc spot welding techniques. Factors affecting the properties of the weld are discussed for both heat-treatable and non-heat-treatable alloys, and criteria for the selection of filler materials are noted. The welding of dissimilar aluminum alloys, and of aluminum alloys to other metals, is also noted. P. K.

A65-19905
RESISTANCE WELDING OF ELECTRONIC MODULES AT NASA'S GODDARD SPACE FLIGHT CENTER.
Assembly Engineering, vol. 8, Mar. 1965, p. 20-22.

Description of techniques used at NASA's Goddard Space Flight Center for the layout and assembly of high-reliability resistance-welded electronic modules. The module design and assembly procedures, the welding equipment, and the testing techniques (including mechanical and metallurgical inspection) which are used are discussed. P. K.

A65-21237 #
WELDING FABRICATION OF HIGH PRESSURE OXYGEN VESSELS FOR LIFE SUPPORT IN SPACE.
Kenneth J. Miller (Garrett Corp., AiResearch Manufacturing Co., Los Angeles, Calif.).
(American Welding Society, Annual Meeting, 43rd, Cleveland, Ohio, Apr. 9-13, 1962, Paper.)
Welding Journal, vol. 44, Mar. 1965, p. 187-193.

Use of the gas tungsten-arc process to make boss and girth welds in AISI 4340 steel hemispheres in welding of high pressure oxygen storage spheres for the Project Mercury Environmental Control System. The fabrication method developed eliminates the use of conventional preheating and postheating procedures commonly used when welding this low-alloy high-strength carbon steel. Welding techniques and a method of controlling interpass welding temperatures are discussed. Physical testing properties of both as-welded and heat-treated weld properties are shown. Metallurgical data and analysis of this welding procedure are illustrated. Preweld planning and quality control procedures which provided excellent in-process controls of all variables are described in detail, and complete reliability of the spheres was consistently demonstrated. Technicians rather than certified production welders were selected to perform the welding. A control welding checkoff list used during welding fabrication is presented. Comment is made that, in space-age welding, it is important to recognize welding as a science rather than an art. F. R. L.

A65-21239 =
THE EFFECT OF PRESSURE ON THE GAS METAL-ARC WELDING OF ALUMINUM ALLOYS.
G. R. Salter (British Welding Research Association, Arc Welding Section, Cambridge, England).
(American Welding Society, National Fall Meeting, San Francisco, Calif., Oct. 5-8, 1964, Paper.)
Welding Journal, Research Supplement, vol. 44, Mar. 1965, p. 107-s to 115-s.
NASA-supported research.
Study of the metal transfer characteristics and weld-bead shapes obtained when arc welding 1/4 in.-thick 5456-type Al/Mg using 1/16-in.-diam. filler metal and argon shielding at ambient pressures between 1 and 30 psia. As the pressure is increased over this range, the rate of metal transfer and arc current drawn increases for a fixed filler metal feed speed, and the arc voltage increases for a fixed apparent arc length. When making butt welds at pressures below standard, the plate penetration is reduced and must be compensated for by increasing the feed speed and decreasing the welding speed. At pressure above standard, penetration and arc efficiency are improved, allowing the use of smaller edge preparations and higher welding speeds. (Author) F.R.L.

A65-21240 #
FABRICATION OF IRON-NICKEL ALLOYS FOR CRYOGENIC PIPING SERVICE.
T. Gottlieb and C. S. Shira (North American Aviation, Inc., Rocketdyne Div., Materials and Processes Dept., Canoga Park, Calif.).
(American Welding Society, Annual Meeting, 45th, Detroit, Mich., May 4-8, 1964, Paper.)
Welding Journal, Research Supplement, vol. 44, Mar. 1965, p. 116-s to 123-s.
Evaluation of the weldability of Fe-36% Ni, which has been found to be superior to conventional piping materials for cryogenic liquid transfer systems. It retains toughness, ductility, and weld integrity at temperatures as low as -423°F, and thus meets the demands of liquid propellant rocket engine systems. The low coefficient of expansion characteristic of this alloy provides design, fabrication, installation, and maintenance economies not available with other alloys. Mechanical and physical properties data for Fe-36% Ni weldments, and various combinations of joints between corrosion-resistant steels, low-carbon steel, and the alloy are presented. The effects of prior processing, pre- and postweld thermal treatment, filler metals, and welding are discussed. It is considered that, in general, welding procedures and precautions for this alloy are no more stringent than those needed for development of high quality welds in 300-series corrosion-resistant steels if proper filler metals are used. (Author) F.R.L.

A65-22683 #
A RATIONAL APPROACH TO INSPECTION AND TESTING OF ENGINEERING WELDMENTS.
Ronald Clough (Canadian Standards Association, Canadian Welding Bureau, West Vancouver, British Columbia, Canada).
(American Welding Society, Annual Meeting and Welding Show, 46th, Chicago, Ill., Apr. 26-30, 1965.)
Welding Journal, vol. 44, Apr. 1965, p. 261-267. 5 refs.
Description of a system for classifying welded products according to their expected load conditions, which can be used to establish inspection and testing requirements for weldments. A classification scheme with eight subdivisions, ranging from low-stress to nuclear and space applications, is presented. The influence of defects on the performance of welds is examined for both static and dynamic loadings. Criteria for the acceptability of welds are discussed, and inspection techniques and related cost considerations are described. P.K.

A65-22684 #
RECENT DEVELOPMENTS IN PLASMA WELDING.
G. Cooper (Thermal Dynamics Corp., Lebanon, N.H.), J. Palermo (Dartmouth College, Graduate Business School, Hanover, N.H.), and J. A. Browning (Thermal Dynamics Corp.; Dartmouth College, Thayer School of Engineering, Hanover, N.H.).
(American Welding Society, Annual Meeting and Welding Show, 46th, Chicago, Ill., Apr. 26-30, 1965, Paper.)
Welding Journal, vol. 44, Apr. 1965, p. 268-276. 22 refs.
Description of the use of a gas-stabilized plasma arc for fusion welding. Studies using high-speed photography of the transferred-mode plasma arc are reviewed. It is shown that, when the arc column and its cool outer sheath are properly controlled, extremely good welds can be obtained. Single-pass butt welds in metals up to 1/2-in. thick are readily achieved without the need for edge preparation or filler metal. Butt welds in thicker sections are characterized by a "wineglass" configuration with the stem portion approaching the narrow width of welds produced by the out-of-vacuum electron-beam process. The use of increased power levels should make it possible to make single-pass welds in materials up to 2-in. thick or more. Alternate plasma-torch geometries are discussed. P.K.

A65-22685 =
POROSITY IN TITANIUM WELDS.
D. R. Mitchell (Titanium Corporation of America, West Caldwell, N.J.).
(American Welding Society, Annual Meeting and Welding Show, 46th, Chicago, Ill., Apr. 26-30, 1965.)
Welding Journal, Research Supplement, vol. 44, Apr. 1965, p. 157-s to 167-s. 14 refs.
Discussion of various factors affecting porosity in titanium welds. Experiments are described which consisted of a series of welds with systematic variations in welding parameters and joint-preparation procedures. The effects of these factors, and of pickling variables and metal-filler additions, on the porosity of welds in Ti alloys are reviewed. A mechanism is described by which hydrogen may produce porosity in Ti welds, and is suggested that hydrogen, in a form other than dissolved uniformly in the metal, causes the porosity. It is found that gross porosity can be effectively eliminated or reduced by pickling in a solution containing 35% HNO_3 and 5% HF immediately before welding. P.K.

Subject Index

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